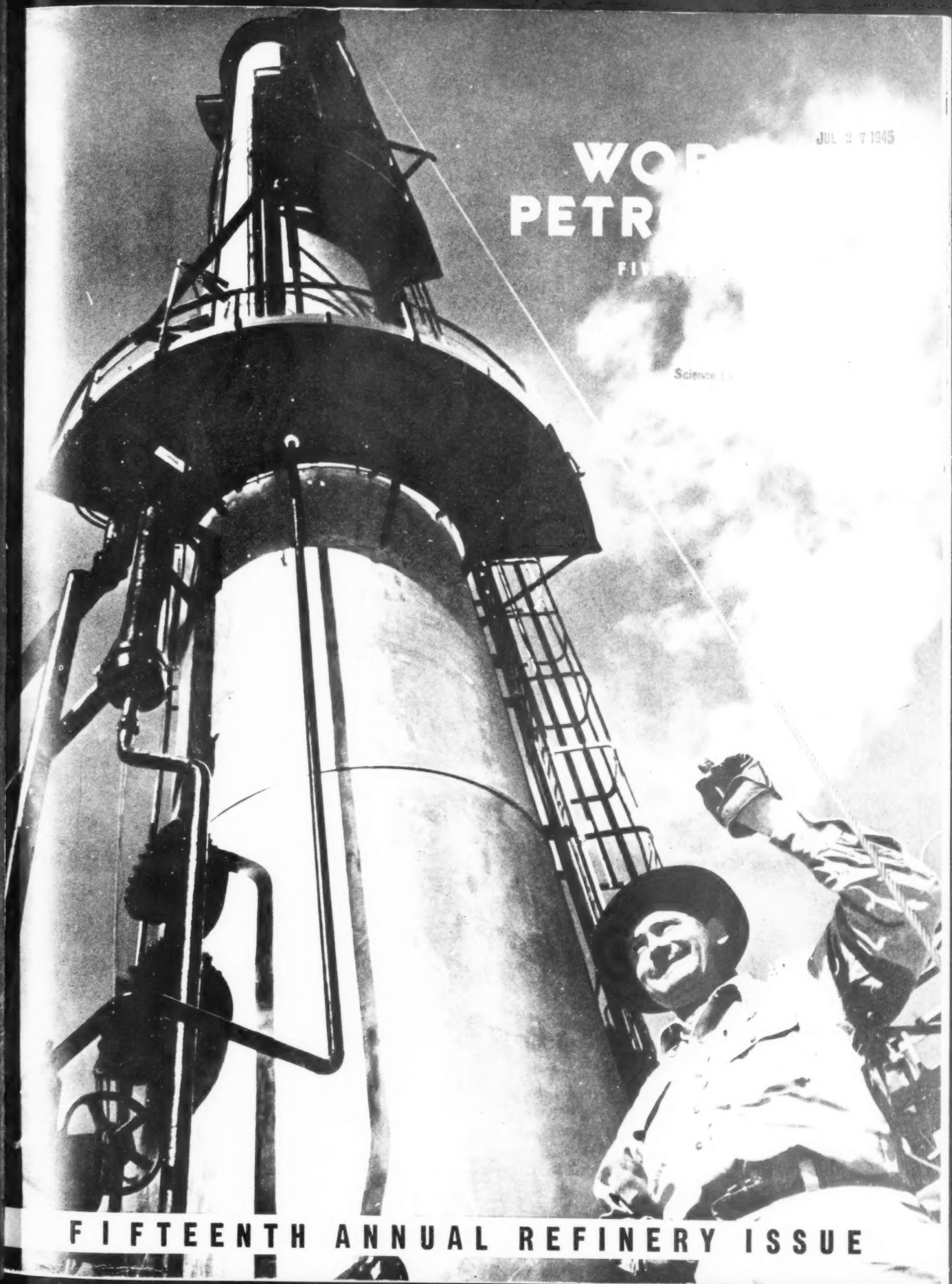

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WORLD PETROLEUM

PUBLISHED BY MONA PALMER

THE MANAGEMENT PUBLICATION OF THE INTERNATIONAL PETROLEUM INDUSTRY

VOLUME 16 | REFINERY, 1945 | NUMBER 8

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Front Cover — Giant Superfractionator Tower, Pacific Coast Refinery of Texas Co.

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SUBSCRIPTIONS: Annual subscription is offered at the flat rate of $5.00 (U. S.) postpaid. Single copies are obtainable at 50 cents. • Address all correspondence regarding subscriptions to the publishers at Orange, Connecticut, or 2 West 45th Street, New York 19, N. Y. Address all correspondence regarding editorial and advertising matters at 2 W. 45th St., New York 19, (Tel. MUrray Hill 2-7333). Published by Mona Palmer Trustee under the will of Russell Palmer.

BRANCH OFFICES: London: Georgian House, St. James, London, S. W. 1 • Mid-Continent Advertising Manager: O. F. Cozier, 415 McBirne) Bldg., Tulsa 3, Okla. (Tel. 4-5555) • Mid-West Advertising Manager: Wilard R. Cotton 307 No. Michigan Ave., Chicago 1, Ill. (Tel. Franklin 2508) • Michigan Manager: R. F. Pickrell, 314 Stephenson Bldg., Detroit 2 (Tel. Trinity 1-0790) • Cleveland Advertising Manager: Frank J. Enright, Union Commerce Bldg., Cleveland 14, Ohio (Tel. Main 5693). Western Advertising Manager: Walter S. Johnson, 412 West 6th Street, Los Angeles 14, Calif. (Tel Mutual 1391). Eastern Advertising Manager, Ralph F. Scholbe, 2 West 45th Street, New York 19, N. Y. (Tel. MUrray Hill 2-7333).

EDITORIAL

REFINING INDUSTRY – WAR AND PEACE

FOR three and a half years past the refining industry has been engaged in a monumental task, first in constructing a great network of plants for the manufacture of new and complex types of fuel and, second, in producing these fuels in volume so great as to beat into defeat and submission the most powerful forces that could be marshaled by nations that had long been studying war and preparing for it.

The task is not yet completed. Enemy aggressors in Europe have been brought to complete and humiliating surrender. But on the other side of the world Allied forces still confront an antagonist more obstinate and barbarous than any faced in the European theatre. Until complete destruction has been spread over the Japanese empire and virtual annihilation visited upon its armies there can be no let down in the flood of petroleum poured out to keep the mighty war machine of the Allies moving in ever increasing might and at ever accelerating speed toward the goal of victory.

In a struggle in which tens of millions of citizens have played some part and in which the productive forces of the nation have established a record of achievement never before written in so short a time it would be invidious to assign chief credit to a single industry. But at least it can be said of oilmen that their accomplishment has met every requirement of the United Nations and has been a vital factor in the success that thus far has attended their arms. As General Eisenhower has told the American people the application of overwhelming power is not only the surest guarantee of success in war but brings that success with the greatest possible saving of lives that otherwise would have to be expended. It is in the attainment of these objectives that the oil industry has rendered outstanding service. By providing aviation fuels of supreme quality and in enormous quantity refiners have enabled Allied aviators to outfly and outmaneuver enemy air forces and to cripple his power of resistance by destruction of his means of production and transportation through mass bombing.

Concentrated assaults upon Nazi factories, communication lines, ports and terminals by thousands of planes that literally filled the sky; complete obliteration of whole cities and constant harrassment and disorganization of enemy troops inside their lines or on the march; these were new and irresistible developments in warfare. They exemplified the application of that overwhelming power on which General Eisenhower lays such great stress and they were made possible by bringing into play the full resources of the American oil industry which no other nation possibly would have matched. Outstanding incidents of the war such as the first flight over Tokio, the dramatic runs of the Red Ball Express and the dashes of General Patton's tank army across France and Germany, as well as less spectacular but essential operations, were made possible only by oil—and oil provided and consumed by the millions of barrels. The production of overwhelming power has been the everyday task of the oil industry in its special field.

Without slackening in any degree its concentration upon the job in hand the industry has reached the point where it can begin to consider the readjustments that it must make when that job ends and the changes that will come with the restoration of peacetime conditions. The problem of reconversion is less difficult than that of some other industries because it does not involve the wholesale scrapping of facilities created to serve the needs of war. Most of the processes and a great part of the equipment installed in carrying out the war program can be adapted to post war production. Nevertheless, great changes will be required. The emphasis will be on different products. The purchasers will be some millions of private users instead of military authorities intent only upon the fulfilment of requisitioned amounts meeting certain specifications. Distributing organizations must be rebuilt and old trade connections must be reestablished or replaced by new ones. Fortunately, as a result of progress made during the war, the industry will be able to offer better products in wider variety than ever before.

That the industry is alive to the necessity of satisfying these future demands and entering upon a new era of virile competition is indicated by the extensive plans already drawn up for the establishment of enlarged facilities and for the modernization of plants that have become obsolescent because of inability to make normal replacements. The investment required for improvements already decided upon runs to hundreds of millions of dollars for American refineries alone.

Outside the United States the industry faces the vast work of repairing the damage wrought by the war and constructing new plants to take care of increased production in many fields. The prospect before the world is one of rapid restoration and great expansion in the years that lie directly ahead.

Checking Turbine Meters — Central Power House, Bayway Refinery. Photo Courtesy Standard Oil Co. (N. J.)

FULL SPEED AHEAD IS STILL OIL INDUSTRY'S DIRECTIVE

By Ralph K. Davies

Deputy Petroleum Administrator
Petroleum Administration for War

WAR reports have painted dramatic pictures of gigantic naval exploits, the deployment and redeployment of millions of men, of great bombing missions over Berlin and Tokyo, of complete railway systems—locomotives and all—being flown over the towering Himalayas, of an entire Chinese Army being moved by air transports.

These accounts generally omit any reference to the petroleum products required for such vast operations, without which, in fact, none of these exploits would have been possible. Prodigious volumes of oil must be kept flowing without interruption to the far-flung fighting fronts through the long supply lines stretching halfway around the earth.

It has required 63 billion gallons of these products to date from this nation alone.

The oil industry of the United States has furnished to the military forces of the United Nations more than a billion and a half barrels of petroleum products since Pearl Harbor. Of almost 8 million barrels of crude oil produced throughout the United Nations since that time, 75 percent has been furnished by the United States. Of the three billion barrels of gasoline refined in the United Nations, 82 percent came from the refineries of the United States. And they produced 85 percent of the aviation gasoline used by United Nations military forces.

The refining industry has an unparalleled record in this war. Almost overnight following Pearl Harbor, the automobile manufacturer ceased to supply his civilian customers and began devoting his factories to tanks and planes. The typewriter company forgot typewriters for civilians and turned to guns and timing devices. Even the watch maker forgot watches for intricate bomb appliances. But the refiner took care of the essential needs of his old customers and supplied the requirements of war too.

What is more, he reached up on the shelf and brought down his test tube triumphs and made deadly instruments of war out of them. His test tube of 100-octane gasoline, costing $30 a gallon, became the power that strangled Hitler and obliterated Tokyo. Now a gallon costs less than 15 cents at the refinery.

There was also the test-tube accomplishment known as solidified gasoline. At the beginning of the war two men arrived at Washington in hope of selling it to the armed forces as a safety compound. Their solidified gasoline became jellied petroleum and it now burns Japs out of their volcanic island caves and reduces the factories of Nagasaki to ashes.

There are at least a hundred such examples. The commercial Diesel oil of yesteryear became the Navy 7-0-2 which now powers the amphibian craft of the Navy, and the heavy duty oil became the invaluable all-purpose motor oil of the Army. At the same time new lubricants were developed for specialized purposes.

For instance, flying men discovered that lubricating oils for airplanes did quite well under ordinary circumstances; but when it came to lubricating the external parts of an airplane motor on the Saharan sands at steaming temperature and then soaring into the near-stratosphere where the temperature was sub-zero, the lubricant took on the consistency of asphalt. They needed a lubricant that would work at both levels with equal efficiency. So they took institutions, devoted before Pearl Harbor to making better products in order to get more sales in a competitive market, pooled their science for the benefit of the war. They soon produced a lubricant which would work so well in any temperature that an airplane motor never blacked-out because of inadequate lubricant.

Whenever the Army or the Navy were confronted with a special petroleum problem they carried it to these laboratories and they generally received a solution within a remarkably short while. Whereupon the military procurement officials would bring their specifications for the new product to the Petroleum Administration for War for immediate production.

Because PAW is staffed with experienced oil men who know where to turn, its officials knew that a refinery at Port Arthur had the best facilities for producing one component which went into a proposed product, while another refinery at East Chicago produced a second component. When all of the components were collected, PAW officials knew that they could be blended best at still another refinery at Houston; and so, with lightning-fast coordination, the special product was delivered to the military. The industry adjusted its stride. It kept moving on as though this additional achievement were nothing.

There is a general impression throughout the world that the refining industry of the United Nations had to undergo stupendous alterations and additions to accomplish its success in the war this far. That is, and yet isn't true. The demands for petroleum required that the refining industry of the United Nations spend almost a billion and a quarter dollars for enlargements and improvements. One billion of that was spent in the United States and about $200,000,000 of it was spent in the rest of the United Nations; but this $1,200,000,000 was devoted to improving facilities so that the production of 100-octane aviation gasoline could be increased from 45,000 to more than 500,000 barrels a day.

For all of this expenditure only three, new, complete refineries were erected. One is at Lake Charles, La., the second at Sweeny, Texas, and the third at Ras Tanura on the Persian Gulf. It was only because the refineries of the United Nations were in such excellent condition and had such extensive spare facilities and "know how" at the outbreak of the war that they have been able to break production record after production record without more of an outlay.

The run of crude for the United States during 1944 was approximately 4,551,000 barrels a day. This record is scheduled to increase so that for 1945 and 1946 the average runs each year will be nearly 4,800,000 barrels daily. These figures compare with 3,391,000 barrels per day of the crude runs of 1939. In order to meet these high scheduled runs it will be necessary for the United States to import substantially increased volumes of crude oil. During 1943, for example, the United States imported only 37,000 barrels per day of crude oil; in 1944 the total of 122,000 barrels daily was imported; in 1945 the average is expected to be about 170,000 barrels per day, and by 1946 the average is scheduled to rise to 250,000 barrels per day.

As the crude throughput of U. S. refineries increased, concomitant increases took place in foreign refinery operations. Although these foreign increases were less in volume than those of the United States, the proportionate rate of gain exceeded the rate experienced in this country. The total runs in foreign United Nations areas, excluding Russia, in 1942, were about 1,090,000 barrels per day. In 1946 foreign refinery runs are programmed at a rate of about 1,750,000 barrels per day, representing an increase of more than 60 percent since 1942. It is interesting to note that this rate of increase, percentage wise, is almost double the rate of increase in the United States during the same period.

Through all of this period, from 1939—especially from the Pearl Harbor year of 1941—to the present, it cannot be emphasized enough that the industry met every military requirement on time. It also met all essential civilian requirements and managed, somehow, to keep pleasure drivers sufficiently supplied so that they could go back and forth to the butcher shop.

In the achievement of such a record there have been innumerable anxieties. The refineries have been going at full blast so long that there has always been the haunting fear that, during the period of scarcity of materials for replacements, something of such a serious nature might go wrong that the schedules would not be met. The refiner was also beset by constant misgivings that he might discover any day that his most essential technicians were called into military service. And, above all, there was the monumental, plaguing thought that the ever shifting, unbalanced, demand for products might throw the whole machinery out of kilter.

With the entrance of the United States into the war, the refining industry of this and some of the other United Nations became a unit for operating purposes. The most and the best out of any refinery was combined with the most and best out of all other refineries so that altogether they made up a total which always met war demands. When one refinery was long on all-purpose gasoline and short on Navy Special, PAW scurried about and found somebody else long on Navy Special, and short on all-purpose gasoline. It had to.

Likewise, whenever a refinery was in danger of losing too many of its men to the armed forces, or it needed scarce replacement parts in a great hurry, or it had labor difficulties, it called on the Petroleum Administration for War for help—and got it!

There was a two-way stretch in the band which held PAW and industry together; and one rarely, if ever, let the other down. Neither could afford to.

Back in the days when everything was confusion and we were hoisting the nation onto a wartime footing, we told ourselves hopefully that once Germany and Italy were knocked out of the war we could, perhaps, take a breather and conquer Japan with comparative ease. Victory has come in Europe, but we have discovered there isn't anything to the dream that Japan will be a pushover.

The United Nations literally blasted the Nazi war machine to bits. In doing so the American Air Forces dropped nearly 100,000 tons of bombs during almost 270 raids to knock out at least 75 Nazi-owned or held refineries. Whenever a Nazi refinery exhibited signs of starting up again, the Air Force knocked it out. Toward the end, while the Nazis were making desperate efforts to build underground refineries, every known restriction was placed by German commanders on the use of their motor power. The Germans, at the moment of surrender, practically fell on their knees from their feet, and not from the cushiony seat of any volkswagon.

All of which leads to the very obvious conclusion that Victory in Europe has not been attained without dumping upon the doorstep of the United Nations more problems. It is unavoidable that we should be deeply concerned over conditions in the liberated European countries. The availability of at least a minimum quantity of petroleum supplies is necessary to restore and support the essential economies of the liberated areas. If these nations were denied essential oil supplies, it seems inescapable that the result would be disease, chaos, and collapse. The United States has vital interest in preventing any such conditions. This is desirable not only from the standpoint of promoting the peace of the world, but also, the prosecution of the war with Japan can be accelerated in many ways by mobilizing the resources of Europe.

Taking Europe as a whole, the principal effect of the war, so far as petroleuem operations are concerned, has been the destruction of terminal, storage, and distribution facilities, synthetic oil manufacturing plants, and oil fields. The situation,, of course, varies from country to country.

Steps are now being taken to rehabilitate essential distribution and refining facilities, and PAW hopes soon to be in a position to survey the producing properties in Central Europe with a view to obtaining as large a volume of production as possible from them.

In Western Europe the capacity to produce crude petroleum before the war was very small, and in consequence countries in that area were under the necessity of importing crude petroleum to supply their refining industries. With the exception of Romania, the same situation existed in the countries of Middle Europe.

During the war the productive capacity of Romania declined due to the lack of further development. Due to development of fields discovered just before the war, production in Hungary and Austria was very substantially increased although the total volume is comparatively small. Germany was also able to increase crude production only to a moderate extent.

It would accordingly appear that the countries of Western Europe are in no better position to supply their requirements of crude petroleum than before the war and that Hungary and Austria are the only countries in Middle Europe which may be in an improved position.

Particular countries having relatively important refining industries, and in which serious war damage is known to have been done to some or all of the plants, include France, Romania, Italy, and, of course, Germany. In the case of the latter, havoc has been wrought not only on the refining installations for crude petroleum but also on the synthetic and substitute fuel plants which furnished a substantial proportion of the Axis supplies. At the present time, a mission composed of technical experts from American industry is making a comprehensive survey of these plants and refineries. Part of these experts' objectives is to appraise the existing physical condition and manufacturing capacities of the plants.

Aside from the question of war damage, it must be borne in mind that critical shortages of materials and manpower in Europe during nearly six years of war would inevitably result in severe depreciation, aside from the direct effects of Allied bombing raids, extensive removal of equipment by the Germans, etc. A tremendous repair and replacement program will be needed to compensate for this depreciation and war damage, not to mention the need for modernization resulting from the obsolescence of pre-war processing methods.

It is contemplated that essential material, machinery, and equipment will be furnished by the United Nations to facilitate, where necessary, rehabilitation of producing and refining properties that may be utilized in the furtherance of the petroleum supply program and also to facilitate the orderly distribution of essential petroleum products.

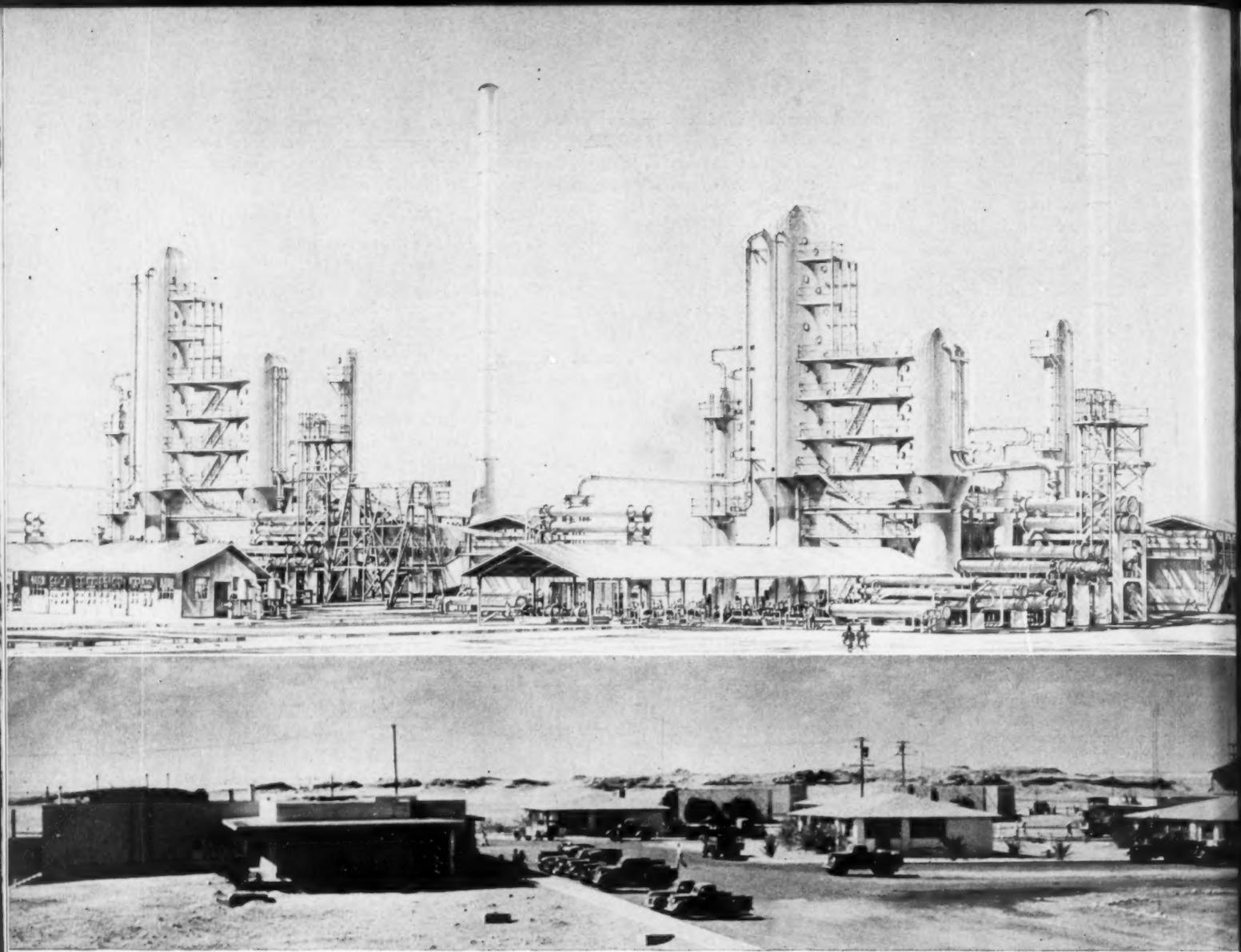
American oil companies have extensive properties in many of the countries heretofore under Axis control and PAW has been informed that most companies intend to rehabilitate their properties as speedily as equipment and trained personnel become available. The situation in this respect varies, of course, from country to country. Poland, Germany, Romania, Hungary and Austria are the principal crude oil producing areas of Europe. PAW does not yet have the complete information that is needed from those countries because clearance has not been obtained for the free entry of American technical and operating personnel.

It is expected that the rehabilitation of oil properties will be privately financed, and the Petroleum Administration is seeking to expedite this type of activity, where it is considered to be essential, through the establishment of priorities on the necessary materials and equipment.

This war could never have been fought in places more unhandy for the United Nations. At no time has a battlefield been closer to a major source of petroleum than 1,500 miles. That applied to the European theatre, and it can be said more emphatically with reference to the Pacific. As the Allies move their men and equipment into Asian waters, as much petroleum and its products will be required to complete their job on Japan as was previously required on both fronts. It requires, for example, a hundred tankers to set down 100,000 barrels of products in Manila every day of the year, and Manila is only one of the hundreds of depots in the Pacific.

Inasmuch as operations in the Asian waters will

(*Continued on page* 144)



Top: Sketch No. 1—Two Three Stage Crude Stills Each of 25,000 Barrels per Day Capacity.

Above: Dhahran, Field Headquarters of Arabian American Oil Company.

50,000 BARREL RAS TANURA REFINERY Will Increase Supplies to Armed Forces

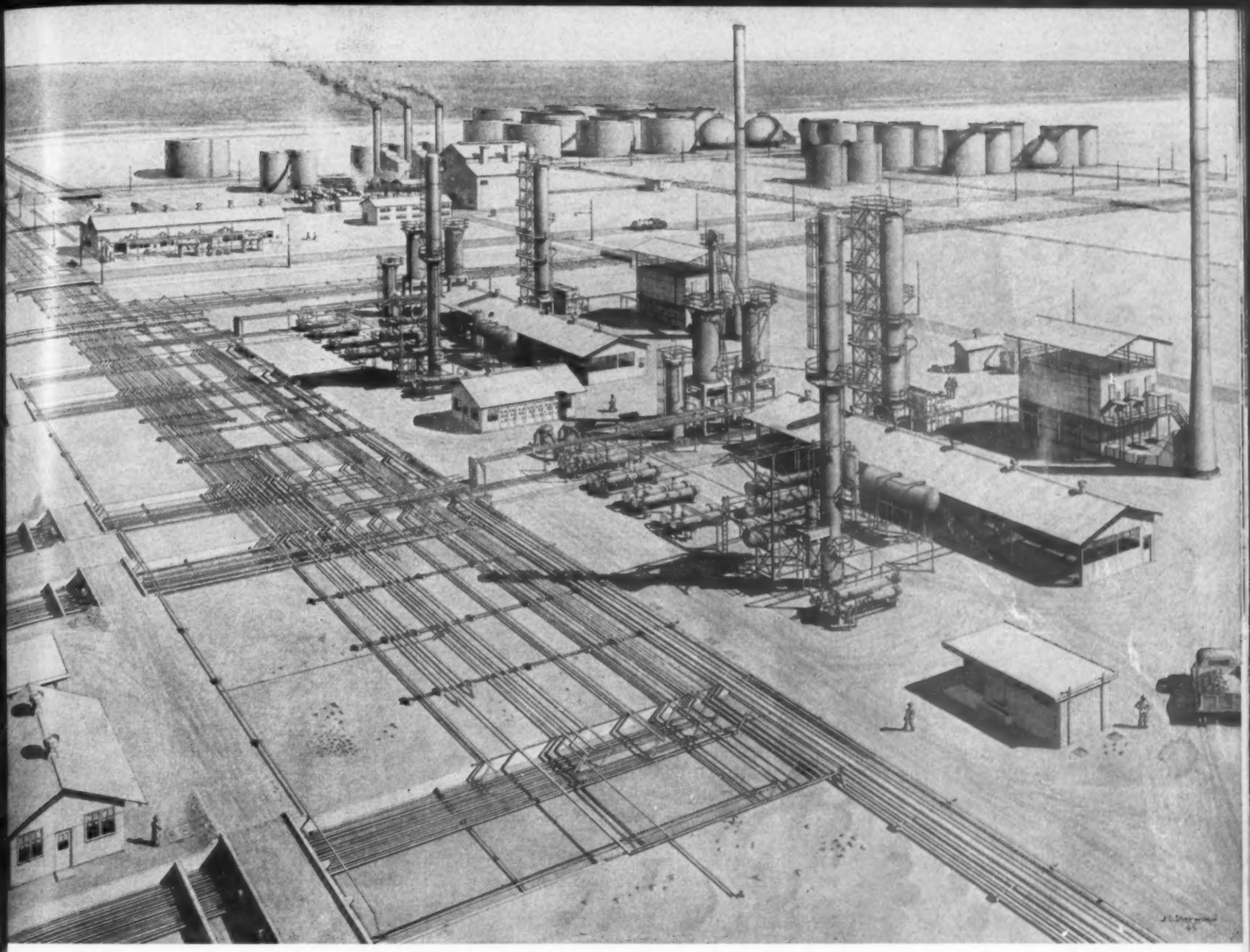
New Plant of Arabian-American Oil Company Built Under Difficult Conditions with Materials Transported 12,000 Miles from the United States Will Begin Partial Operation in September Utilizing Saudi Arabian Crude.

ONE of the unique war projects undertaken by the petroleum industry will soon be ready to turn out products at Ras Tanura in Saudi Arabia. This is the 50,000-barrel-per-day refinery of the Arabian American Oil Company, the full production of which will be made available to the armed forces of the United Nations.

In many respects, this project is like a large number that have been successfully completed within the United States during the war period, but in addition to the problems connected with such undertakings, it presents many others peculiar to its location in the Persian Gulf. These special problems arise from the facts that the refinery site is 12,000 miles in any direction from the home office of the Company and that practically nothing was available locally to assist and support the construction or operation of the refinery. The only materials of construction available are sand and rock. Everything else has to be imported.

Map A is a general vicinity map that shows all the petroleum facilities in this area. The Damman field is the principal source of crude for the new refinery. It also is supplying some crude to the Bahrein Petroleum Company's refinery on Bahrein Island. A 10-inch crude line with 60,000 barrels per day capacity connects the Dammam field with the Ras Tanura refinery.

As a backup source of crude, a 12-inch pipeline will be installed from the Abqaiq field to Dhahran. A new discovery has been made at Qatif along the route of the 10-inch pipeline which will provide an additional supply to feed the refinery. The refinery is located along the route of this pipeline on Ras Tanura peninsula six miles northwest of the terminal at Ras Tanura harbor. This point is as near to tide water as is practical and is shown on Map B.



Sketch No. 2—Two Thermal Reformers; 18,000 KW Electric Generating Station.

The coastal area in this vicinity is characterized by low-lying sand dunes ranging up to 1000 feet wide and from six to twenty feet above sea level. Back of these dunes the land is flat and at extremely high tides much of it is inundated. A soil study indicated that it would be necessary to found all heavy structures on piles to be driven into a sandstone stratum, the surface of which lies about ten feet below the general ground elevation. These piles were driven and most of the foundations were poured without any general grading. Subsequently, the area was brought up to a general grade of six feet above the mean high tide by borrowing from adjacent sand dunes and other high points. The fill will be completed by dredging from Tarut Bay.

The two 25,000 barrel-per-day crude stills are shown on the accompanying sketch, No. 1. The straight run gasoline will be reformed in two thermal reformers shown in sketch No. 2. Other refinery equipment necessary to produce motor gasoline, diesel oil, and fuel oil is being provided.

Steam and electricity will be supplied by the refinery plant for the refinery area and the adjacent activities. Three 220,000 pound capacity boilers will generate steam at 650 pounds pressure. Three 6,000 KW turbine generators will generate 13,800 volt, 60 cycle, 3-phase power. The well water available contains about 3000 parts per million of total solids and is limited in supply. Accordingly, the boiler plant is operated on a closed system and all condensate is conserved. Steam is bled off from the turbines and circulated through evaporators to produce steam to be used in the refinery. Underground cables are used in the main electric distribution system within the refinery area.

Cooling and condensing water will be pumped from the Persian Gulf and disposed into Tarut Bay across the Peninsula. The plant has been designed for a cooling water temperature of 95° F, which is reached quite generally throughout the summer months. Because of this high temperature, an unusual quantity of cooling water is required. The total demand is 70,000,000 gallons a day.

The intake is an open ditch extending 600 feet out to sea to a low water depth of ten feet and protected by rock breakwaters on both sides. A low lift pumphouse (see sketch No. 3) equipped with propeller type pumps elevates the water into a concrete ditch that carries the water approximately 2000 feet to a central settling basin. There it passes through travelling screens to the suction of four refinery pressure system pumps located in a high lift pumphouse whence it is distributed through concrete pipe to the process units. After use the water is discharged through separators into Tarut Bay.

To provide against contamination of bay waters the refinery sewer system is divided into five parts: (1) clean water system which takes cooling water from steam condensers and discharges it to the ocean without treatment, (2) intermediate water system which takes cooling water from closed heat exchangers and discharges it through single step API separators to Tarut Bay, (3) alkaline oily water system which takes all alkaline process water and washdown and passes it through a single stage API separator of standard design and a hay filter before discharge to Tarut

Sketch No. 3—Low Lift Pumps to Move 70,000,000 Gallons of Salt Water Daily Through Open Ditch Intake Channel.

Bay, (4) acid oily water system which collects all acid waste waters and discharges them through a dilution sump to the oily water separator, (5) sanitary sewer system which discharges all sanitary sewage through a comminutor to a primary settler and thence to Tarut Bay. Settled solids are digested in a pre-stressed reinforced concrete tank.

Since the refinery elevation is only six feet above high tide all oily water and sanitary sewage is pumped. Clean and intermediate waters are carried in pressure sewers until they discharge into lined ditches outside of the refinery proper. All of the large size distribution and sewer mains are made of centrifugally cast reinforced concrete pipe made on the job.

Approximately 4,000,000 barrels of all welded steel storage and working tanks have been installed. Products from the refinery will be transferred through five pipelines to shipping storage tanks at the terminal, which is six miles away.

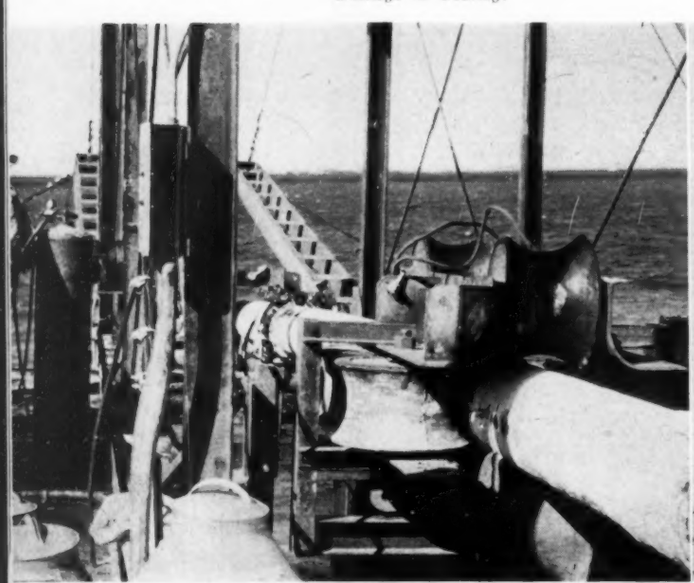
In 1939 facilities were installed at the terminal to ship crude oil through a submarine loading system. The anchorage is in 50 feet of water, 3300 feet offshore. In 1940 a 3000-barrel refinery was built at the terminal to supply the local demand for products. This refinery has supplied the great fleet of construction and automotive equipment required to built the refinery now being erected.

Ras Tanura is the only point along the Persian Gulf coast of Saudi Arabia that is suitable for developing into a first class deep-water harbor. A wide and deep approach from the main fairway in the Persian Gulf has been marked so that any ocean-going vessel can make its way safely and conveniently into the harbor.

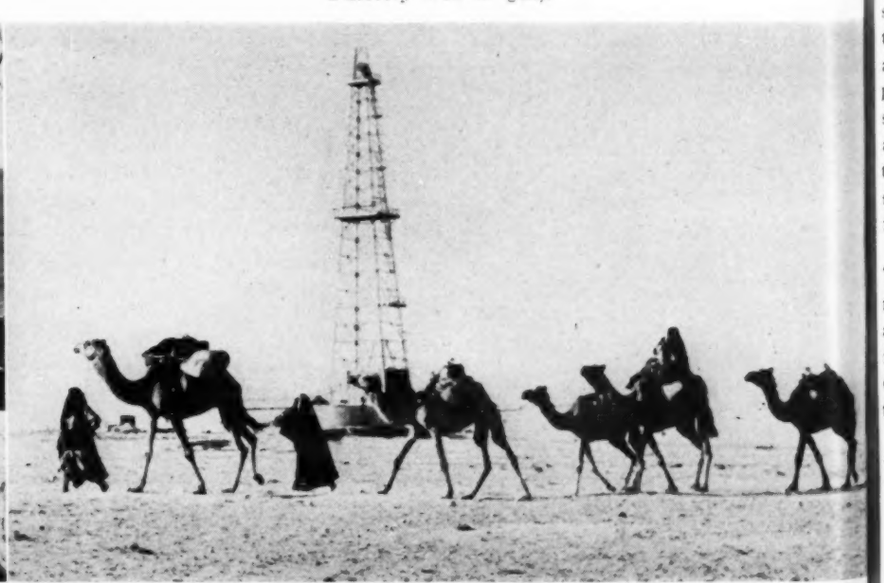
Before this refinery project was started all material was offloaded from freighters onto lighters that were unloaded at a rock filled material pier on the west side of the peninsula. As a part of the current project a four-berth wharf has been built on the east side of the peninsula extending one-half mile from shore where the water is 35 feet deep below Indian springs low tide. This wharf will be used for receiving materials and loading petroleum products.

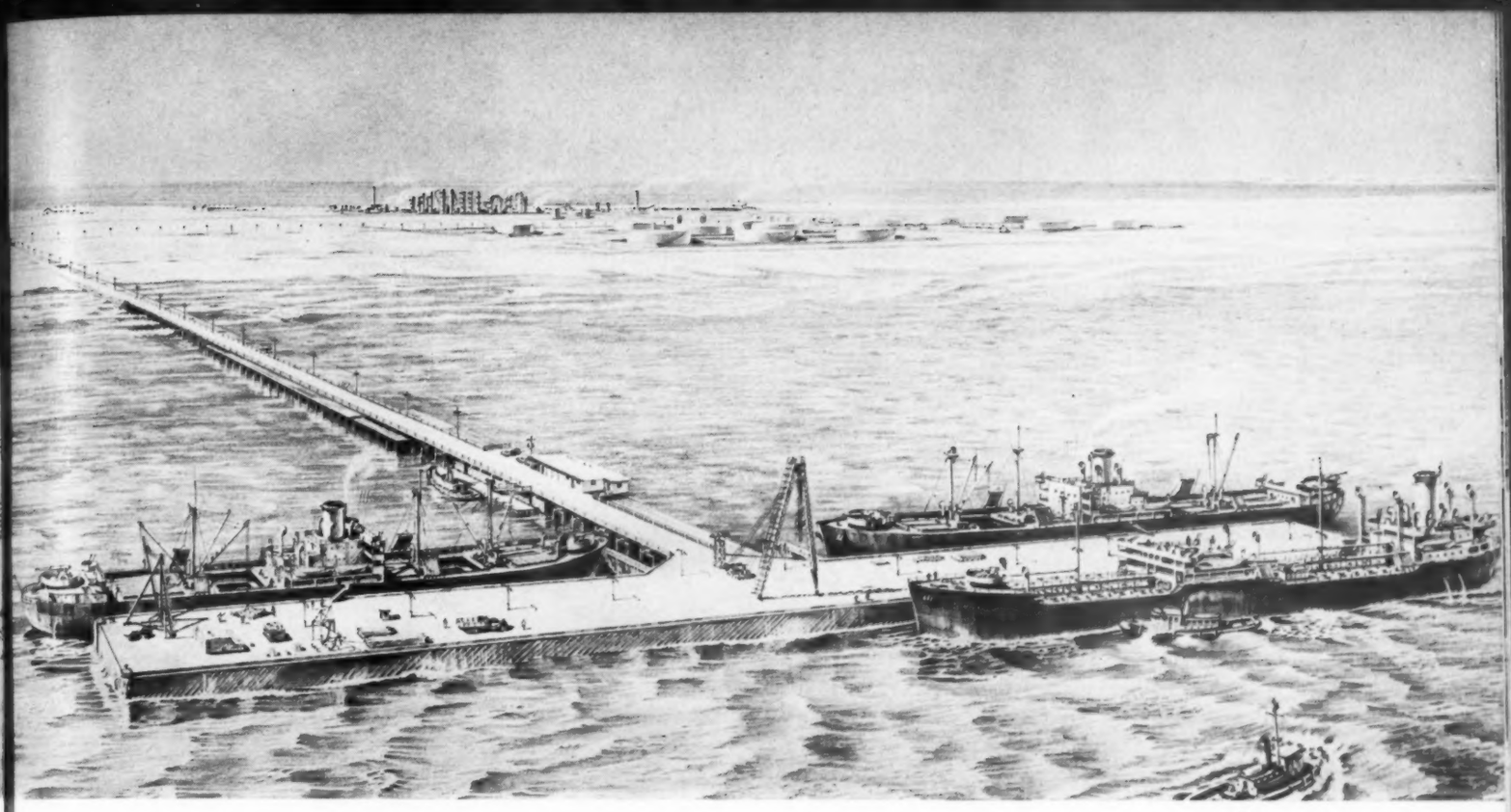
The wharf structure is built of steel piles decked with timber. Sketch No. 4 shows the complete wharf equipped with gear for handling heavy lifts up to 125 tons. About 500 long tons a day can be offloaded from ships directly onto the

Submarine Pipe Launched Through Rubber-covered Rollers to Avoid Damage to Coating.



Discovery Well at Qatif.





Sketch No. 4—Four-berth Wharf in 35 Feet of Water One-half Mile from Shore, Showing Shear Leg Derrick in Center.

dock, which is capable of handling transport trucks and trailers, tractors, Athey wagons, and any other unit with axle loads up to 30 tons.

The pipelines are run on outriggers on the approach and under the deck at the loading berths. Products and bunkers can be loaded simultaneously. Water, electricity, air, and steam are available for ships calling at the port.

The project was approved late in February, 1944. In spite of very difficult working conditions sufficient progress will be made by September of 1945 to permit running the refinery at half its ultimate capacity. The whole project is scheduled for completion before the end of the year.

Most of the field work in 1944 was preparatory in nature. When the project was approved the only facilities available were the small refinery referred to above, the rock pier on the east side of the peninsula, two cottages, and bunkhouse space for 32 men. Because of wartime limitations on procurement of material and equipment and shipping space for its delivery, there was practically nothing available from company stocks with which to start the projects. In fact, all surpluses that could possibly be spared from the existing trucks, housing materials, tools and so forth had been turned over to the armed forces.

The first shipments in April, 1944 consisted primarily of materials for the construction camp and the material pier and construction necessary for the first stages of construction. Automotive equipment followed as soon as it could be obtained.

The first of the construction force arrived about the first of June and divided its time between unloading ships, building the material pier and temporary housing facilities. As the camp grew the force was increased to accelerate the camp and other preliminary work.

The first efforts were handicapped by the excessive heat of the Persian Gulf summers with temperatures usually reaching a maximum of between 100 and 110°F every day with exceptionally high humidity. A strong sand-laden wind is seasonal in June and July. In 1944 this wind lasted well into August and interferred more than was expected with material lightering and wharf construction.

There are no public utility companies, commercial shops, supply houses, transportation systems, or other aids to construction that are normally found in the United States. Accordingly, one of the first things that had to be done was to install a temporary power plant which ultimately consisted of 20 85 KW engine driven generators and four field boilers to supply camp and construction requirements.

Complete shops, adequate to handle the maintenance of the refinery and related equipment plus some repairs to tankers, tugs, launches and barges, are being provided. This equipment was shipped as early as possible and installed on a temporary basis to assist in the construction work. The main shop building has 46,000 square feet of floor area and houses the machine, boiler, plumbing, tin, air conditioning, instrument and electric shops. Carpenter, paint and tent shops and tool storage buildings are also provided.

Similarly, garage facilities were set up on a temporary basis to maintain the more than 400 pieces of automotive and construction equipment required on the job. Complete permanent garage facilities are being provided in a 25,000 square foot building.

There were no roads in the vicinity when work was started and very little material known to be suitable for good roads was available. Accordingly, it was decided to carry on the project without waiting for or depending on the usual hardsurfaced roads. In the course of its operations in the Arabian deserts, the company has developed a special low-pressure sand tire for automobiles and trucks that successfully floats over loose fluffy sand or the soft marshy areas. All automotive units were equipped with these tires, and construction proceeded while roads were being developed. Essential roads in the refinery area are now being built to facilitate the local dense traffic. A rock quarry and crushing plant established about 12 miles from the site provided enough waste rock material for these essential roads.

Because of the upset in trade in the Near East caused by the war there is a shortage of food in Saudi Arabia. It was, therefore, necessary to ship in not only food required by the American construction force but also enough to augment the local labor's meager supply. Mobile refrigerator facilities were used at first to store perishables. A commissary building has now been

built for food storage. It has 30,000 square feet of air conditioned space and is equipped with 6700 cubic feet of frozen storage and 20,000 cubic feet of chilled storage.

The main skilled force was sent out from the U. S. It was supplemented by some semi-skilled labor recruited in nearby countries. The bulk of the labor force is Arab.

There are practically no industries in Saudi Arabia, as a consequence of which the Saudi Arab nationals have had substantially no experience in mechanical trades. Under company supervision a large number have been trained in many of the crafts and some have become highly qualified. However, the refinery project required about 7000 additional Arab employees most of whom had to be drawn from the coastal towns or the Bedu tribes. A comprehensive and intensive training program has been set up on the project to develop local skills as rapidly as possible. In spite of the lack of background in construction work the Arabs have proved to be apt students and have increased in usefulness very rapidly. It is worthy of comment that the Arab has been able to learn English more quickly than the Americans learn Arabic.

The American construction camp was completed early in 1945. The bunkhouses are 24-room suites. The mess hall can handle the full force at one sitting. Other facilities include a large recreation hall equipped with lounges, bowling alleys, pool tables, and soda fountains, a library, an outdoor theater, a fully equipped 40-bed hospital and a variety of outdoor recreation facilities. All quarters and general camp buildings are air conditioned. Various camps have been established for the local and other foreign labor with adequate hospital facilities and other equipment to insure sanitation, health and comfort.

As the camp capacity expanded, the size of the construction force increased beyond that necessary for the work on camp facilities, and work on the refinery, itself, got underway with the driving of the first foundation pile on November 19, 1944. However, it was not until February, 1945 that enough men could be spared for refinery construction to ensure substantial progress on all parts of the plant.

While the preparatory work was going on in the field, equipment was being fabricated in the U. S. to the maximum extent practical so that the time required to erect the refinery could be reduced to a minimum. All the large columns and vessels were fabricated either in one piece or in large sections that were carefully fitted before shipment. Where the resulting pieces were larger than could be handled on railroads this assembly work was done at tide water. The heavy pieces were transferred from the ships to barges with the 125 ton capacity shear leg derrick built on the Ras Tanura wharf. All piping 3-inch and over was prefabricated. Electrical equipment was unitized to facilitate field assembly. This program of prefabrication was amply justified by the saving in time and labor to erect the refinery units.

Associated with the Ras Tanura Refinery project was the construction of a 12-inch 34-mile pipeline from the Dammam field to the Bahrein Petroleum Company's refinery on Bahrein Island to meet its expanding requirements for Arabian crude. Seventeen miles of this line was laid under water across the Bay of Salwa between Saudi Arabia and Bahrein.

The pipe for the crossing was protected with Somastic Pipe Coating applied in the United States. It was assembled in double lengths on the Saudi Arabian shore and hauled to a construction barge on which the line was welded.

Cathodic protection stations were also installed on each shore to drain a constant electric current from the pipe as a further safeguard against corrosion should the coating become damaged at any point.

The first field operation for the submarine line was a complete hydrographic survey of the area between the island and the mainland. The best route for the line was selected and marked by driving piles at intervals of 1,100 feet, so that the pipe-laying barge could readily follow the course. The piles were also used as anchors to secure cables with which the barge was held in place fore and aft or moved along by winches on the deck. Regular anchors to the bottom controlled the barge against lateral movement.

The construction barge, along with eight other smaller barges, was built, launched, and equipped at Ras Tanura. It is 180 feet long and 40 feet wide, has a narrow gauge railway down the center, an overhead monorail crane, electric light plant radio station, running water, compressed air, welding machines, asphalt kettle, a large portable crane, powerful winches to handle the cables, and a cook house and mess hall.

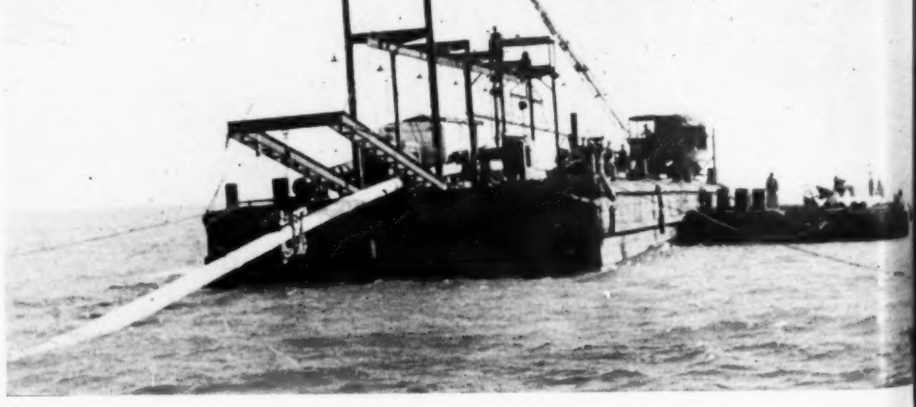
Lengths of pipe ferried to the barge were picked up by crane and placed on cars on the railway. Here they were welded together and the welds were covered with Somastic. The barge was moved ahead by pulling on the cables. The pipe was fed from the stern over rubber-coated rollers which prevented damage to the coating. In deep water, a smaller barge followed and supported the pipe on more of the rubber rollers, suspended from outriggers on each side.

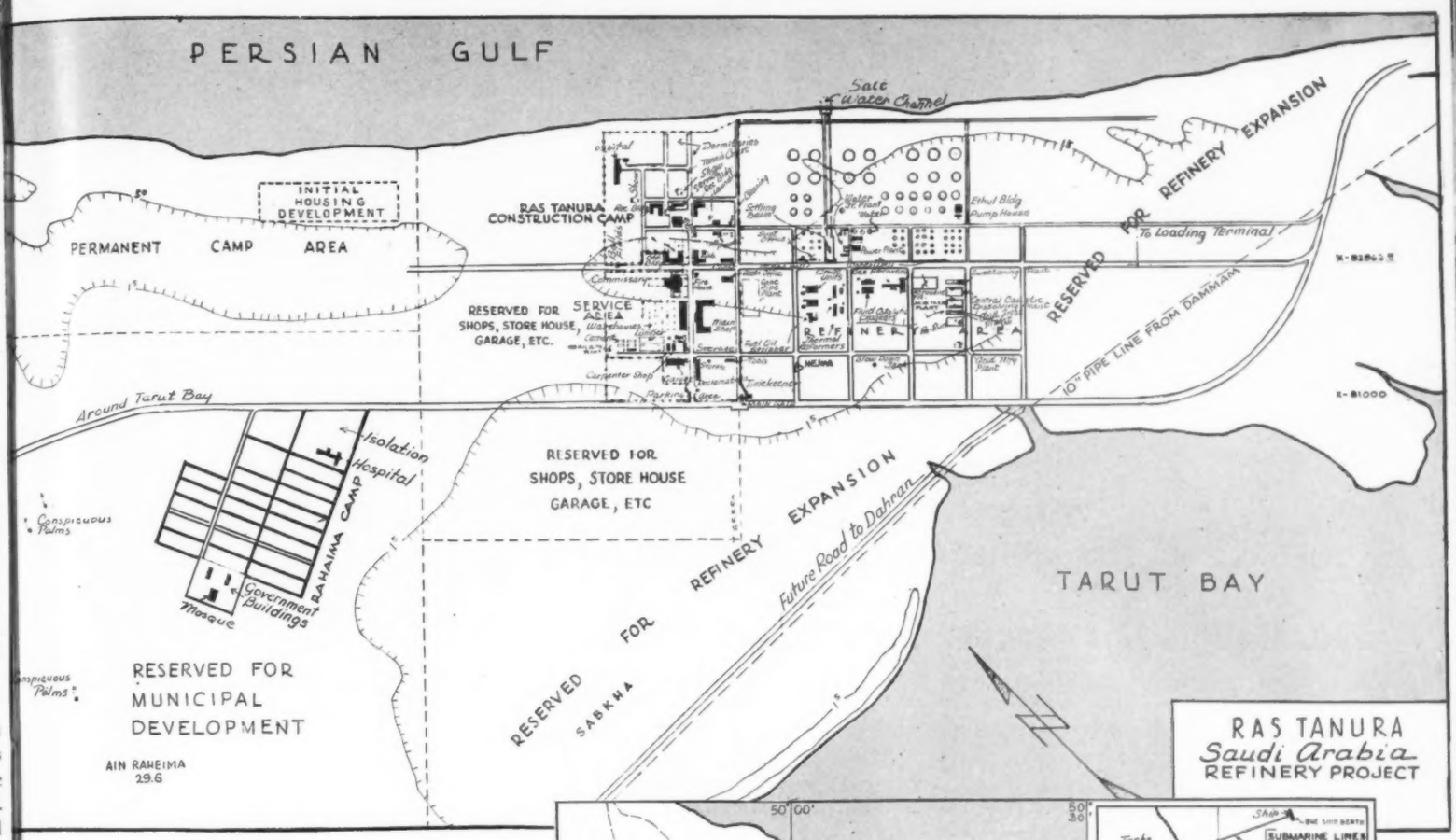
Storms and high seas caused interruptions. In one of the worst storms the side anchors gave way and allowed the barge to drift out of line enough to kink the pipe being laid. A diver with a hydrogen torch had to cut out the damaged section under 35 feet of water before the laying of the line could be resumed. Seas often broke over the barge. Some workers suffered from seasickness. But the job was pushed steadily ahead. Night shifts under floodlights supplied by a Diesel-operated generator on the barge were begun late in December.

With all this, the actual elapsed construction time for the submarine portion of the line was 91 days, compared with the engineers' estimate of 90 days. The actual working days were 65. The worst storm of the season broke just 21 hours after the line was completed.

The last weld was made on February 28. Then the line was given a 1200 pound hydrostatic test which it withstood perfectly. After connecting it to the tanks and pumps at Dammam Field, oil pumpings were started. The water in the line was displaced, oil reached Bahrein March 3rd, and the stream has been flowing continuously ever since with no signs of leakage or other trouble.

Barge, 180 Feet Long and 40 Feet Wide, That Laid 12-Inch Underwater Pipeline from Saudi Arabia to Bahrein Island.



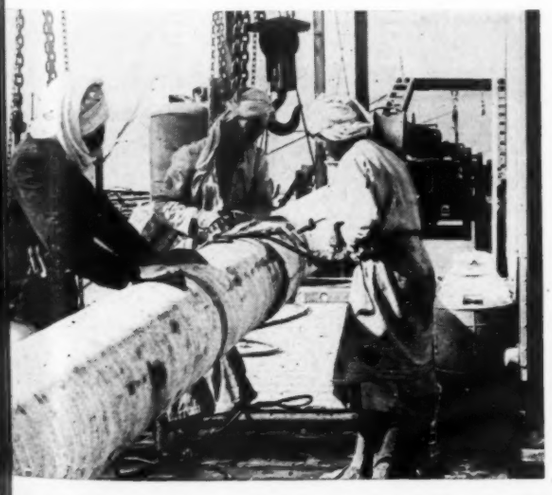


Map A.

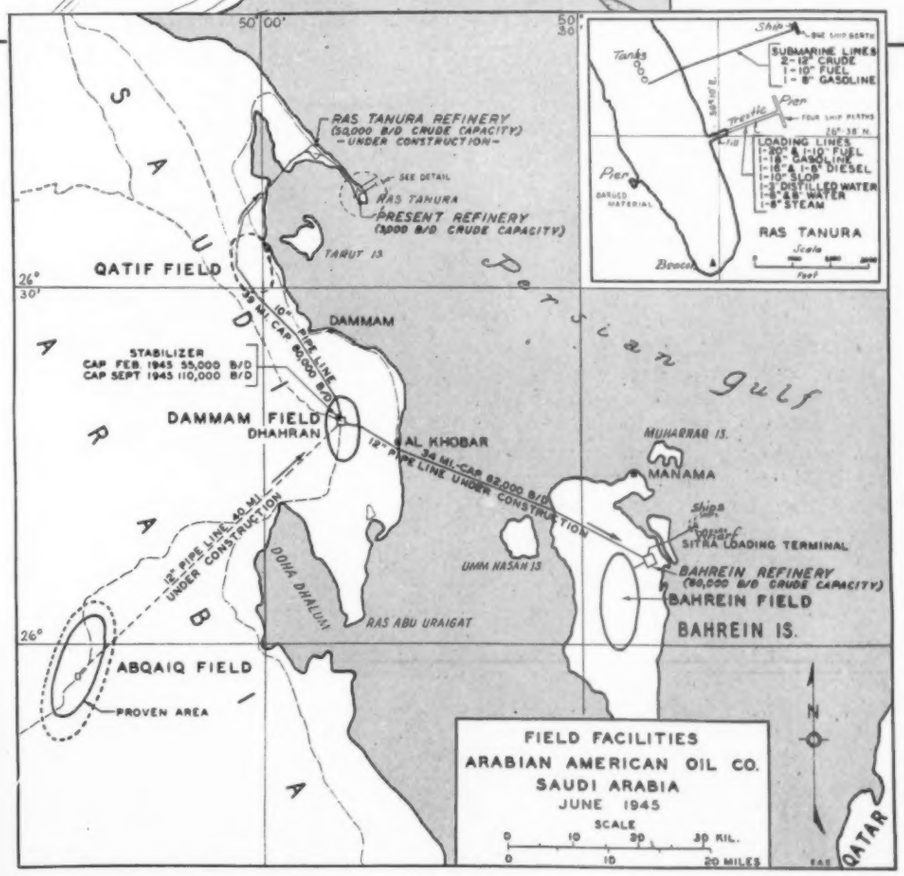
The 12-inch line from Abqaiq will tap the Arabian American Oil Company's largest proved oil field. Much of this line will be built through heavy shifting sand-dune country which will pose special construction problems rarely met in pipeline work.

All the crude delivered to the refineries will be stabilized at Dhahran to remove all the hydrogen sulphide and thus make the crude sweet for handling from this point on.

The field headquarters of the Arabian American Oil Company are at Dhahran, where its first producing field is located. There a camp suitable for the purpose has been established. Permanent housing facilities are now being built at Ras Tanura to take care of the operating force at that point.



Left: Ends of Pipe Left Bare for Welding.



Map B.

Reformer Units, Dubbs Crackers, Polymerization Plant and Fluid Catalytic Cracker.

BAHREIN'S GREAT NEW REFINERY HAS THROUGHPUT OF 65,000 BBLS DAILY

Expanded Capacity, Including Construction of Large Catalytic Cracking Unit, Achieved Under Wartime Difficulties of Transportation, Manpower and Materials Supply Enables This Persian Gulf Installation to Provide Substantial Quantities of Aviation Gasoline, Diesel and Fuel Oils for Armed Forces of the Allies

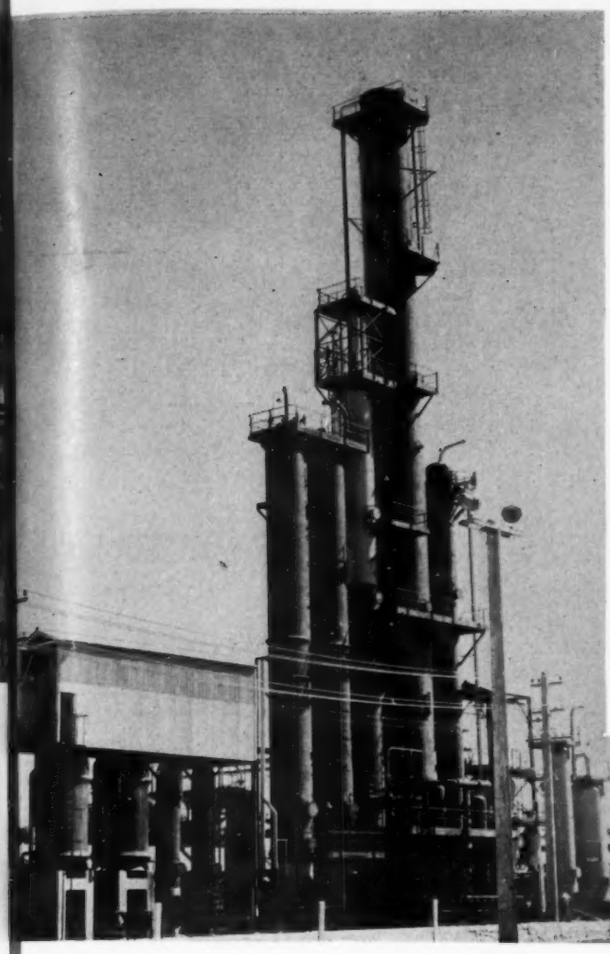
AN important outpost for the supply of petroleum products to Allied forces throughout World War II has been the oil field and refinery on the island of Bahrein. Midway along the eastern shore of the Arabian peninsula, in the Persian Gulf, Bahrein has occupied a strategic position for supplying fuel to naval and land units operating in that part of the world. Beyond the effective range of enemy air power it has been free from attack except for one abortive attempt by Italian bombers early in the conflict although it has had to carry on under blackouts and other precautionary measures. Consequently, Bahrein has been able to render noteworthy though unpublicized service to the United Nations and has greatly expanded its facilities in order to make this service more effective.

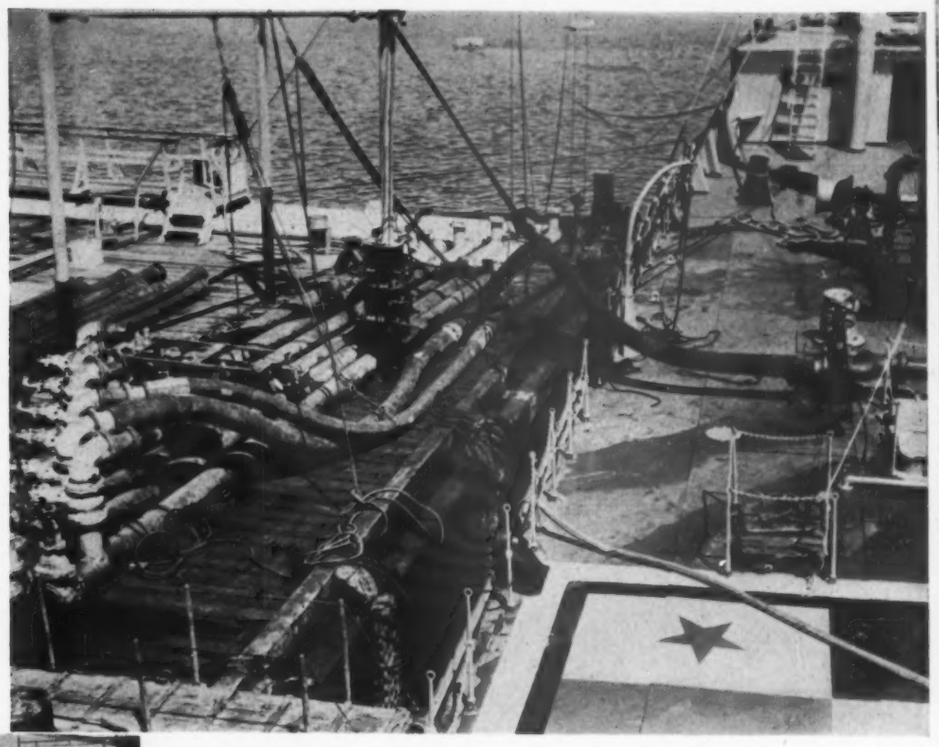
Originally developed by Standard Oil Company of California, Bahrein first attracted attention among the oil fraternity in 1932 when its discovery well, Jebel Dukhan No. 1, was brought in flowing 100 barrels hourly from 2008 feet. Prior to that time the small islands, of which the largest is 12 miles wide and 27 long, had won notice mainly as a seat of Persian Gulf pearl fisheries, an industry that still claims the attention of a good part of the native population during several months of the year. A hereditary sheikdom, it has been under the protection of Great Britain since early in the last century when the British undertook the task of clearing up the remnants of piracy in the Persian Gulf area.

In 1934 when six wells had been drilled and the field had been proved as a substantial producer within its limited area the Bahrein Petroleum Company began construction of a shipping terminal on nearby Sitrah Island with submarine pipe lines leading across the shallow waters from the producing field on the main island. At the same time plans were drawn for a refinery of 10,000 barrels daily capacity which later was raised to 25,000 barrels as more wells were brought in and deeper horizons were located. The refinery was completed in 1937 when 50 wells had been drilled on Bahrein. Its actual operating capacity was something over 30,000 barrels. It included two Dubbs cracking units of 12,000 to 14,500 bbls. daily charging capacity.

With the coming of war, and particularly after Japan's attack upon the United States had extended the combat area across the Pacific, great quantities of petroleum products were needed to maintain the air, sea and land operations of Allied forces in the Middle and Far East. With the main source of supply 12,000 miles distant in the United States it was logical to establish facilities for the production of the special fuels required for military use in those refineries nearer to the scene of operations which remained under the control of the United Nations.

Awali Camp — North Half.





Above: Isomerization Plant.

Upper Right: Sitra Loading Wharf — Hoses Feed Oil to Tanker.

Right: Depropanizer and Stabilizer Columns.

Out of this situation came the decision to double the size of the Bahrein refinery, raising its daily crude capacity to 65,000 barrels and to include in the enlarged plant a unit for the production of 100 octane aviation gasoline. Such a construction task in the midst of war, with the multitude of competing demands for materials, the lack of skilled workers and the shortage of shipping space, offered almost insuperable difficulties, but in view of its obvious advantages in aiding the prosecution of the war it was decided to undertake it. Government agencies in Washington granted the necessary priorities on materials, several engineering firms were employed to design the complicated facilities, the international firm of Bechtel-McCone was engaged to build the equipment, and the company recruited an operating and maintenance staff.

The work involved many problems aside from the actual erection and equipment of the plant itself. Practically everything connected with the refinery and its accessories had to be transported half-way round the globe. The only exceptions were the rock and sand required for foundations which were found on the island and the cement used which came from India. Forty thousand tons of structural material were shipped from American ports. The contractor's force of 750 and the several hundred company employees had to be similiarly transported. Materials and equipment for housing the workers, for offices and health and recreational facilities, had to be provided; refrigerator ships were employed to bring in food.

From the beginning of its operations the company has maintained a model camp, with houses designed to provide the maximum of comfort in a trying climate, with a hospital, clubhouse and playgrounds, but these facilities have had to be expanded to accommodate the additions to the foreign population in connection with the enlargement of the refinery. The company also has enlarged the technical training system which it maintains in cooperation with the Bahrein government and through which it has been able to familiarize a large number of natives with mechanical operations and the skilled use of tools.

Construction of the new plant was started in January 1944 and in spite of all difficulties, the last unit was completed in seventeen months and started operation in June 1945. It is now engaged in producing substantial quantities of high octane gasoline, regular motor fuel, illuminating oils, Diesel and fuel oils, the greater part of which is going to the use of Allied armed forces. Of its crude supply, about 20,000 barrels is drawn from wells on Bahrein and 45,000 barrels comes from fields of the Arabian American Oil Company which, like the Bahrein Company, is jointly owned by Standard Oil Company of California and The Texas Company.

Two-stage atmospheric and three-stage atmospheric-vacuum crude distillation units are provided to give flexibility as required to produce a wide variety of distillate and residual stocks. Crude distillation products consist of straight

Tank Field, Acid Recovery and Clay Treating Units.

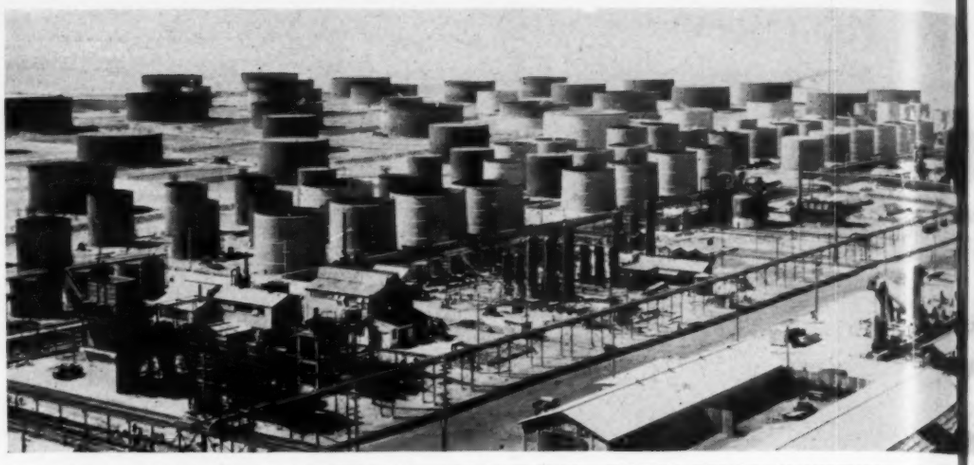
run gasoline (which is subsequently rerun to a low end point straight run gasoline and thermal reformer charge in a separate rerun column), kerosene distillates, Diesel oils and residual stocks. Since the octane number of the straight run gasolines is low, a reformer charge comprising all fractions of straight run gasoline except those lighter than heptane is thermally reformed in a Dubbs thermal reforming unit of 6,500 barrels daily capacity. A second similar reforming unit is nearing completion. No major corrosion problems are encountered on this reforming unit, the sulfur content of the charge stock being low and only traces of hydrogen sulfide being produced in the reforming operation. Gray clay treating towers permit the production of low gum content water white gasoline from this reforming unit and no additional processing other than sweetening and inhibiting is required to permit the sales of this gasoline as a component of U. S. Army 80 octane all purpose motor gasoline. Operation of the reformer stabilizer is controlled to strip butanes and a portion of the pentanes from the reformed gasoline, the pentane fraction eventually being produced as a separate gasoline blending stock which can be used for volatility and vapor pressure control in gasoline blends. Butanes from the thermal reforming unit have in the past been charged to a liquid phosphoric acid type catalytic polymerization plant and at the present time are a component of charge stock to a sulfuric acid alkylation unit.

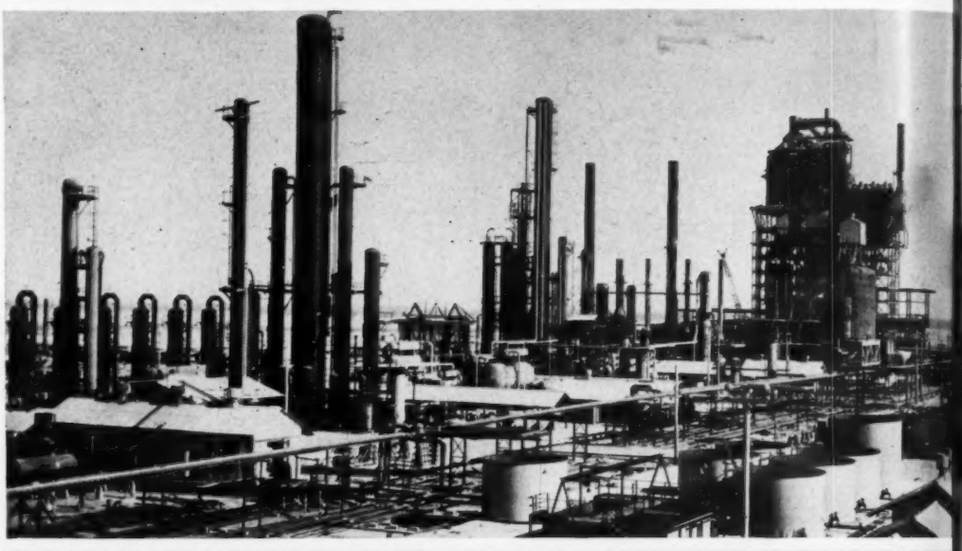
Kerosene distillate is processed in an Edeleanu plant at rates up to 9,600 barrels daily to produce illuminating kerosene which has low sulfur content and is exceptionally paraffinic as indicated by the fact that I.P.T. smoke points on these kerosenes run as high as 45 mm. The paraffinicity and high smoke point of these kerosenes make them particularly suitable for use in railway signal lamps, kerosene burning incubators and refrigerators and similar uses where exceptionally good kerosene burning characteristics are required. Edeleanu extract is acid treated, rerun and blended with a special gasoline stock to produce power kerosene having a motor octane number of 60-61.

Diesel oil production at the present time is being controlled for the manufacture of large volumes of U. S. Navy Diesel oil. Both this and heavier Diesel oils produced at this refinery have high cetane numbers which average close to 60 and pass the rigid 212°F. copper strip corrosion test in which the Diesel oil is required to leave a copper strip untarnished after three hours submersion at a temperature of 212°F. Similiar excellent corrosion tests are obtained when a silver strip is substituted for the copper strip.

Two Dubbs 3-coil thermal cracking units permit optimum utilization of crude residual stocks as required to balance motor gasoline and fuel oil requirements. These units, which can be operated to either a marketable cracked tar, pitch, liquid coke or coke, can charge up to 14,500 barrels of residuum per calendar day. Considerable use of high chrome alloys is required in furnaces and columns, both because of temperature-pressure considerations and to combat corrosion. Although only about three percent of the total sulfur content in thermal cracker charge appears in the stabilized gasoline, some hydrogen sulfide is produced and the units require protection against high temperature hydrogen sulfide corrosion. Most of the sulfur in the charge stock remains in the residuum and, when these units are operated to coke, the coke production contains 5-6 percent sulfur which cannot be materially reduced by subsequent calcination. Gasoline production from this unit is partially depentanized, and the pentanes cut which contains up to 0.2 percent mercaptan sulfur is caustic washed for mercaptan removal. Although the volume of pentanes subjected to this caustic washing amounts to only 6-10 percent of the total debutanized cracked naphtha, a large proportion of the mercaptans present in cracked naphtha is removed by the caustic washing of these pentanes with subsequent improvement in gasoline stability and saving in tetraethyl lead consumption.

Thermally cracked naphtha is lightly acid treated with 93 percent sulfuric acid in a two-stage treating plant and subsequently rerun at moderate temperatures in a two stage rerun unit. Re-





Above: Bahrein's Only Filling Station at Manama.

Center: Alkylation; Isomerization and Catalytic Cracking Plants.

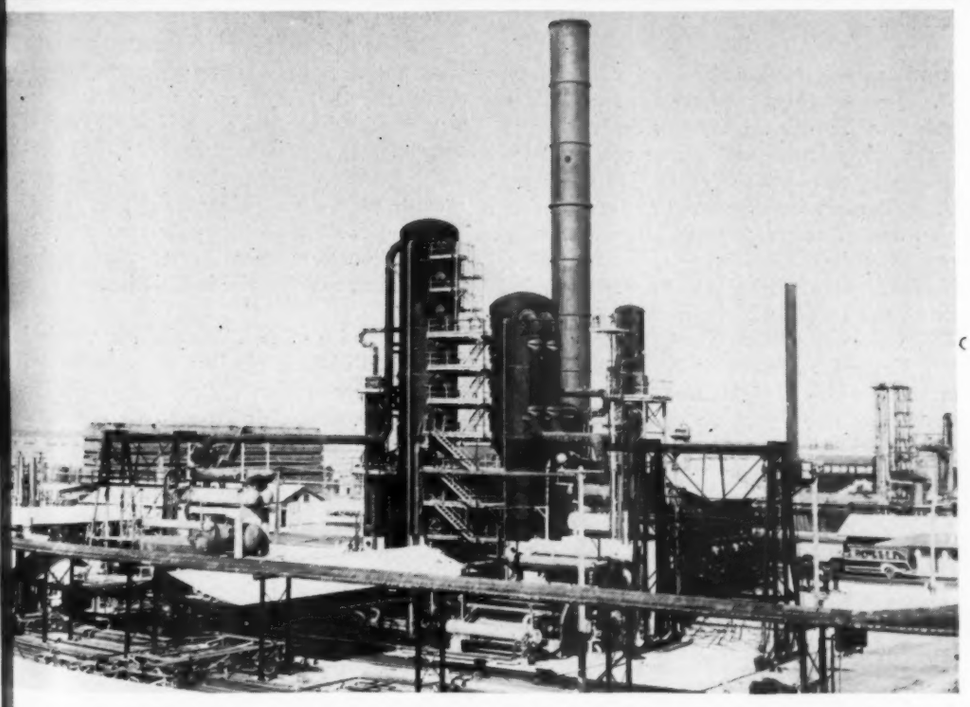
run cracked gasoline as well as other gasoline stocks are sweetened in "split sweetening" lead sulfide plants, a modification of the conventional lead sulfide sweetening operation which removes polysulfide sulfur from the gasoline by controlled contacting with gasoline in which the mercaptans have been converted to mercaptides by sodium plumbite solution. The sweetened gasolines contain only traces of polysulfide surfur and are stable to exposure to sunlight and quite susceptible to oxidation inhibitors.

Operation of the sweetening plant requires moderate quantities of sodium sulfide, a chemical which is produced locally from caustic soda by caustic washing hydrogen sulfide containing gas streams from the thermal cracking units.

Expansion of refinery facilities to permit manufacture of approximately 6,000 barrels of 100 octane aviation gasoline daily required the installation of alkylation and isomerization plants and a catalytic cracking unit and numerous auxiliaries. Selection of the sulfuric acid alkylation process was predicated on the difficulties and expense involved in transporting hydrofluoric acid to such an isolated location, and a sulfuric acid alkylation plant of approximately 3,500 barrels of aviation alkylate daily was decided upon. A vapor phase isomerization process was originally chosen for the refinery but was eventually converted to a liquid phase isomerization plant prior to completion.

Below: Modern Bunkhouses Provide Living Comfort.

Center: Distillation Unit.



After consideration of catalytic cracking processes, it was decided to install a Fluid catalytic cracking unit at Bahrein. Experimental pilot catalytic cracking work was conducted at the Riverside Laboratory of the Universal Oil Products Company to furnish data for equipment design, and on the basis of this and other work it was decided to construct a two-stage fluid unit which would permit primary catalytic cracking in one large reactor and catalytic retreatment of the primary catalytic gasoline in a second smaller reactor. Since information relating to optimum processing of catalytic stocks was most incomplete at that time, the gas concentration and rerunning facilities included as a part of the catalytic cracking unit were designed to permit a wide variety of processing combinations in order to be sure that any subsequent developments in processing could be utilized on the Bahrein facilities.

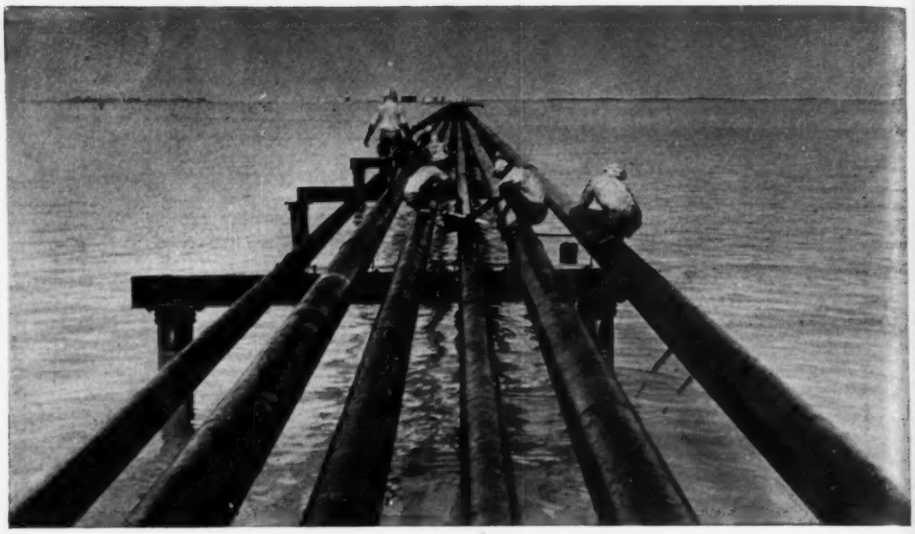
Another feature of this fluid unit which distinguishes it from a number of units in this country was the addition of a primary charge vaporizing system, which comprised a vaporizing furnace, a tar separator and a final charge superheater. This system permitted operation of the vaporizing furnace at substantially less than 100 percent vaporization, with some super-heating of the separated vaporized charge in a second furnace and recirculation of the unvaporized portion of the charge from the tar separator back to the entrance to the vaporizing furnace. A second simple vaporizing furnace also was provided for the charge to the retreat reactor, thus substituting charge preheat and vaporization for increased catalyst recirculation as a means for vaporizing the charge stock.

The gas concentration facilities on the fluid unit comprise absorbers, depropanizers and debutanizers, together with the necessary compressor equipment to assure maximum recovery and essentially complete separation of butanes and butenes for charge to the alkylation plant. Also included are three atmospheric and one vaccum rerun still which provide facilities for preparation of the catalytic retreater charge stock and returning of the retreated gasoline for a number of different possible combinations of catalytic retreatment. A controlled-temperature acid treating plant permits light acid treatment of the catalytically retreated aviation blend stock, since preliminary information indicated that the high temperature storage conditions in the tropics required production of aviation gasoline having excellent stability characteristics.

Butane recovery facilities also were constructed to permit maximum recovery of butanes from

Bapco Hospital Maintained by Company.

the crude still products, since the isolated location of this refinery precludes importation of butanes from outside sources and forces it to be completely self-supporting insofar as alkylation isobutane requirements are concerned. These butane recovery facilities consist of a gasoline stabilizer to which all light straight run gasoline plus the compressed crude still gas is charged and from which an overhead cut consisting of pentanes and lighter is charged to a depropanizer. The degree to which gasoline is depentanized depends on the overall isopentane balance, and these facilities permit the recovery of 60-70 percent of the isopentanes present in the crude without excessive contamination of this isopentane with normal pentane. The depropanized mixture of butanes and pentanes goes from the crude still butane recovery facilities to the isomerization plant, where a butane rerun still separates the isopentane rich cut for storage and permits butanes to be charged to deisobutanizing equipment.



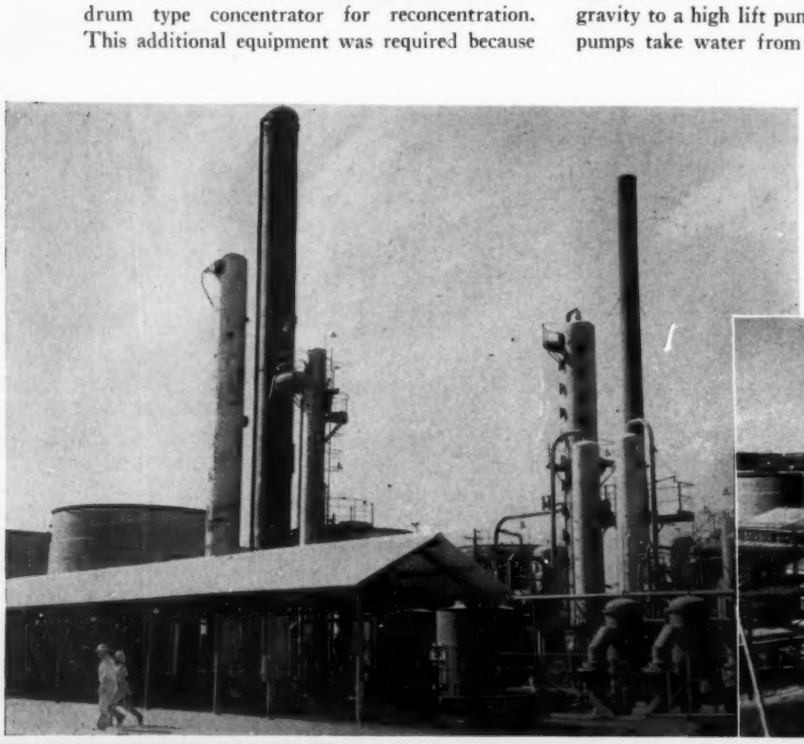
Pipe Lines Leading to Loading Pier for Ocean Tankers — Many More Lines Have Been Added Since This Photograph was Made.

Additional sulfuric acid manufacturing and recovery facilities were required to provide sulfuric acid for alkylation and avoid the production of a large surplus of spent alkylation acid for which there was no refinery demand. The present contact acid manufacturing plant was enlarged and a second smaller acid manufacturing plant was constructed. Spent alkylation acid passes through atmospheric and pressure separators and thence to a "Chemico drum type" concentrator which produces a reasonably concentrated sulfuric acid suitable for fortification to 98 percent acid in the acid manufacturing plants. An unusual feature of this system is the provision of auxiliary air drying towers to pre-dry the very humid Bahrein air which enters the acid manufacturing plant combustion furnace where SO_2 is produced. Although the original acid manufacturing plant had an air drying tower, all water which was removed from the air intake was absorbed by a portion of the sulfuric acid production. In the new system a preliminary air drying tower washes the incoming air with concentrator acid and the acid effluent from this tower is pumped back to the drum type concentrator for reconcentration. This additional equipment was required because high atmospheric humidities would have prevented the production of 98 percent acid unless such special precautions had been taken.

With the new system, concentrator acid is pumped to the 98 percent acid absorption towers on the acid manufacturing plants where it is concentrated to a strength exceeding 98 percent by absorption of sulfur trioxide produced in the contact plant.

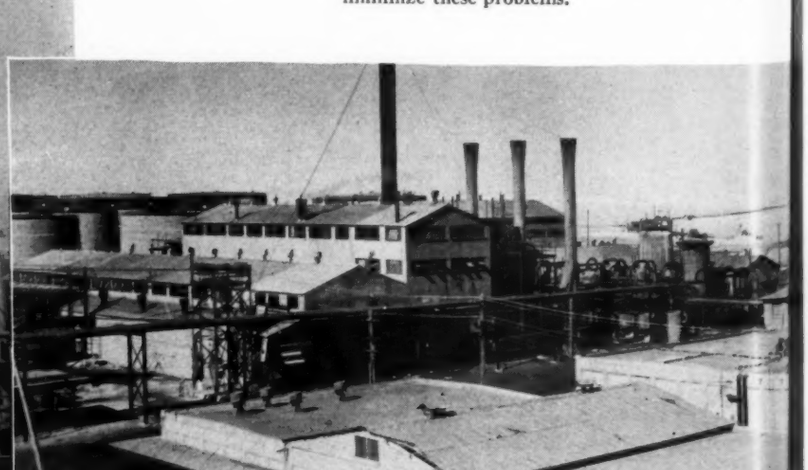
Another major problem was the provision of an adequate water supply for the aviation facilities and, in order to avoid any possible impairment of the Bahrein Island well water supply, facilities were provided to utilize Persian Gulf water for all cooling requirements on the new facilities. This required construction of a salt water intake approximately one-half mile out in the Persian Gulf, at which location low lift pumps can deliver up to 75,000 gallons per minute (with 25,000 gallons per minute of standby pump capacity) into a flume in which the water flows by gravity to a high lift pump house. The high lift pumps take water from the flume and pump it through large reinforced mains to the refinery where the water after passing through condensing and cooling equipment returns through concrete mains to a modern API type oil separator and thence back to the Persian Gulf. The maximum temperature of the Persian Gulf water at the point of intake is about 95°F., which is unusually high for refinery cooling purposes and results in a relatively large demand for water, since, in order to avoid fouling difficulties with condensing and cooling equipment, it is necessary to limit the condenser water outlet temperatures to approximately 105°F. In order to minimize shipment of critical materials from the United States, a concrete pipe manufacturing plant was shipped to Bahrein, and the reinforced concrete pipe required for the cooling water installation was fabricated locally, involving numerous production problems because of the fact that the diameter of some of this pipe is 48 inches.

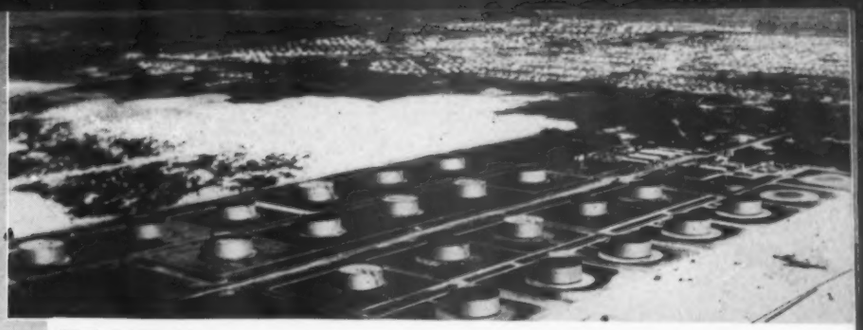
The installation of these new facilities required importation of large numbers of workmen, and this temporary increase in population resulted in development of social and economic problems not previously encountered. It also was necessary to utilize Bahrein labor to the maximum extent, requiring a major local employment program. These problems were simplified, however, by the sympathetic and cooperative attitude of the Bahrein government and the British authorities who worked closely with the company management to minimize these problems.



Left: Gas Recovery Unit.

Below: No. 1 Power Plant.





Above: Servicing Alkylation Plant During Turn-Around.

Left: Pipe Bends Frame Fluid Catalytic Cracking Unit.

Upper Right: Aerial View of Haifa Tank Farm.

Above: Oil Refinery near Balikpapan, Borneo.

REFINING INDUSTRY FACES PERIOD OF RECORD ACTIVITY

DURING the past twelve months the war program of the petroleum industry has moved into high gear and has been sending to the battle fronts a volume of products that would have been considered unbelievable at the commencement of the war. In the United States the majority of the plants constructed for the specific purpose of supplying aviation fuel and other specialized products for military use were completed and in operation before the end of 1944 but a number of important additions have been made since that time. As the plants earlier built, almost without exception, have substantially exceeded their rated capacity in actual operation it was possible to bring about a steady increase in the flow of materials in pace with the expanding scale of land and naval operations until 1,700,000 barrels of crude were being processed daily to sustain Allied military establishments and their supply lines.

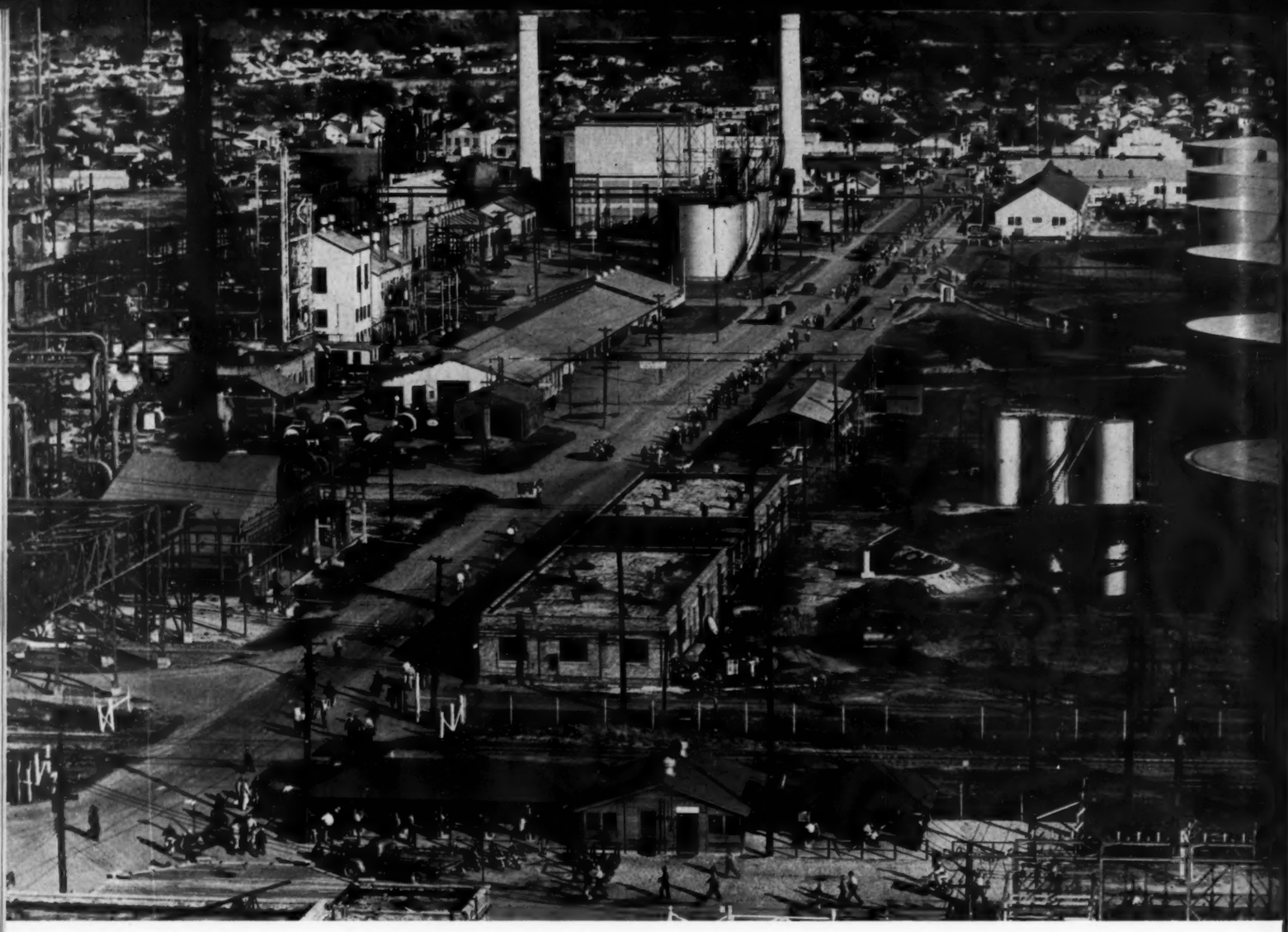
With the enlargement of ocean transportation facilities and the disappearance of the Axis submarine menace it became possible for other producing and refining regions, particularly those of the Caribbean and Middle East areas to contribute increasingly to Allied requirements. In its later stages the European war was completely dominated by the planes, tanks and other mechanized equipment fed by the combined resources of all these plants.

Now that the center of military activity has shifted to the Pacific the problem of oil supply has been intensified in various directions. Because of the greater distances to be covered it is estimated that three cargo ships will be required to move the volume of materials that could be handled by one on the route across the Atlantic. This means that the demand for ship's fuel will be correspondingly increased while the concentration of available Allied air power against Japanese defenses will permit no decrease in the provision of high octane gasoline. More general employment of rocket planes and jet propulsion will call for increasing production of the special fuels suited to such use. On the whole the requirements placed on the refining industry in all areas under Allied control are expected to increase right up to the date of Japanese capitulation and the added capacity being brought into operation by the construction projects now under way, which were described by the Office of Petroleum Administration as "a cushion of safety" undoubtedly will prove to have been wisely provided.

Of the 100-octane gasoline units provided for by this supplementary program several installations are duplicates of others previously constructed at various refining centres. The Texas Company is adding a large unit to its Lockport, Ill. plant and a smaller one is being erected at Leonard Refineries, Alma, Mich. Another new unit is being added to Shell Oil Company's large installation at Houston, Texas, which ranks among the country's greatest concentrations of equipment for the production of petroleum war materials. A large plant devoted to the manufacture of products for military use is being constructed by Gulf Refining Company at Philadelphia. Current additions to facilities for the production of high octane gasoline and other specialized war materials call for an expenditure of $78,000,000 which is being provided by the oil companies concerned.

Aside from the plants included in what may be described as the official war program many companies have installed new processes and equipment for adding to their capacity and increasing their output of high grade products by methods of recovery from low grade materials.

In the fall of 1944 the Deputy Petrolum Administrator for war made a report to the War Production Board based on an inquiry conducted among refiners as to projected extensions or new construction which they might have in view for the immediate post war period. The replies received indicated that nearly all the companies reporting had plans prepared for the installation of extensive improvements and additions to existing capacities. Many of these replies re-



Refinery "Main Street" Teems With Workers.

flected the intention of refining companies that did not construct new units for the manufacture of aviation fuel or other specialized products for military use to install catalytic refining units or other new processes developed in the course of the war. Such action they felt was necessary to enable them to meet the competition of modernly equipped plants constructed since the start of hostilities primarily to supply products for military use. Others proposed the replacement of obsolete equipment which they had been forced to continue in use beyond its normal span because of wartime restrictions upon the use of structural materials. The survey was informal in character and did not cover the entire field. At the time it was made many of the companies had not completed their post war plans and so stated.

A summary of the responses received showed that projects definitely listed for construction in the United States represented a calculated investment of $177,000,000. Of this $91,000,000 was the proposed expenditure for the installation of catalytic cracking units; approximately $50,000,000 was for the production of lubricating oils, greases and waxes; upward of $10,000,000 was for the erection of topping and thermal cracking plants, and the remainder represented facilities for special processes and products. American companies with properties in other countries also reported plans for new refinery construction outside the United States on which they proposed to expand another $176,000,000. Since the time when this survey was made extensive additions have been made to the number and cost of construction projects both within and outside the country.

The inquiry demonstrated that the fear sometimes expressed lest the intense construction activity of the war years would lead to a temporary suspension of such operations with the return of peace was without foundation. On the contrary it appears that many projects which could not be carried out during the past four years will be put under way as soon as the release of materials and manpower makes this possible.

Typical of these installations is one for delayed recycle coking that is now being made for General Petroleum Corporation at its Torrance, California, refinery by the M. W. Kellogg Company. Through this method heavy, tarry crude residues which have not been refinable previously are converted under heavy pressures to light desirable hydrocarbons, gasolines and gas oil distillates without any of the liquid product remaining. Instead some 330 tons of solid coke comprise the end product daily. This type of processing represents practically the ultimate in extraction. The light hydrocarbons obtained will be reprocessed by alkylation to produce more 100-octane gasoline. The additional facilities will have a capacity of from 13,000 to 15,000 barrels of components ranging from high octane aviation gasoline to Diesel and fuel oils and will make the Torrance plant one of the most complete and efficient in the country.

Meanwhile large additions to capacity have been made at the huge refining plants of Standard Oil Co. (N. J.) at Aruba and Royal Dutch Shell at Curacao in the Dutch West Indies. Both these plants have contributed vast quantities of products for use of the United Nations since the beginning of the war and their strategic location in relation to the Panama Canal makes them a factor of primary importance in this respect now that the Pacific has become the main theatre of operations. To meet the urgent demands for petroleum products for military purposes a large catalytic cracking unit for the production of 100 octane aviation gasoline has been added to the Curacao refinery at a cost of $6,700,000 by authorization of Allied military authorities. Recently the Arend refinery of Royal

Dutch Shell on Aruba Island which had been closed down for two years past has resumed operation.

In the Middle East the enlargement of refining facilities has added greatly to the military resources of the Allies. Addition to the big Abadan refinery of Anglo-Iranian Oil Company of a high octane unit along with other installations bringing its daily capacity above 375,000 barrels has made it a tremendous source of war materials supply while the recent completion of the 100-octane installation by Bahrein Petroleum Company on Bahrein Island further augments aviation fuel output for use in the Pacific. The expanded Haifa plant of Consolidated Refineries provides another important fueling post for planes and ships following this route to the East.

Although the production of materials for military use will continue to occupy the capacity of existing plants to the end of the Pacific war new construction for this purpose may be regarded as practically completed. From the engineering viewpoint the refining industry is now preparing to enter upon a new phase, that of readjusting its operations to peacetime needs and possibilities. This task includes two main lines of activity. First is the big job of repairing the widespread damage inflicted during the war; second is the provision of facilities for meeting rapidly rising demands for petroleum products in the post war period and taking care of the great expansion certain to take place in crude production.

The first of these undertakings assumes truly staggering proportions. While no complete survey of the condition of European refineries has been made since the fighting ceased enough information has been gathered to show that from the Atlantic eastward almost to the shores of the Caspian the majority of the plants have been damaged in degrees varying from 50 percent to complete demolition. The extent of the destruction is even greater than was indicated by earlier reports based on aerial observation and affords convincing testimony to the efficiency of systematic bombing. In France the plants in the northern part of the country have been disrupted to an extent that requires practically complete rebuilding while most of those in the south escaped with relatively minor damage. Italy's refining equipment has been largely wiped out. Constant bombing of Romania's refining center in 1944 reduced its capacity nearly 90 percent. The Nazi drive into Russia eliminated a number of plants in the western and southern areas that were overrun. In Germany detailed reports have revealed that repeated ferocious attacks by Allied bombers converted refineries, synthetic plants, storage and terminals into heaps of twisted metal from which little can be salvaged.

It is by no means certain that all these plants will be rebuilt. In Germany it seems safe to say that restoration of the synthetic industry which enabled Hitler to wage a war of tremendous destruction will not be permitted. Such refineries as are allowed probably will be limited to the number needed to supply the needs of a restricted agricultural and industrial economy. In reoccupied countries the decision of the oil companies as to reconstruction will depend upon their estimate of future market demands and to some extent upon the form of government which is established in these countries. Changed conditions may also dictate new locations for some of the plants. But wherever they may be placed the facilities that served Europe pre-war will have to be reproduced somewhere and will call for the investment of some hundreds of millions of dollars.

In the Far East also the numerous plants in the areas overrun by the Japanese in their early conquests either were demolished before their arrival or will be destroyed by the time they finally are forced to withdraw. In most cases the replacement will involve an expenditure equal to the original cost of construction. To replace the facilities lost in the course of the war in these two great areas will require an outlay equaling, if not exceeding, the cost of the entire petroleum war program of the Allies.

Due to the exigencies of war, it is possible that the replacement of destroyed plants will begin earlier in the Pacific region than in Europe. The enemy already has been driven from the oil districts of Burma and Borneo and the recapture of the remaining Japanese held islands of the East Indies may follow long before the war comes to an end. Allied military authorities appreciate the importance of relieving the tension upon trans-ocean transport lines by developing nearer sources of supply. They are prepared as soon as enemy control is released to move in trained crews to reestablish production and to set up limited refining facilities. The oil companies holding concessions in this area have prepared their own engineering plans and are ready to move in close behind the Army and Navy to begin the work of renovation. It is unlikely that supplies from the western Pacific will have a very substantial effect in reducing the amounts drawn from the Western Hemisphere but they may provide a valuable supplement to these particularly in the matter of ship's fuel.

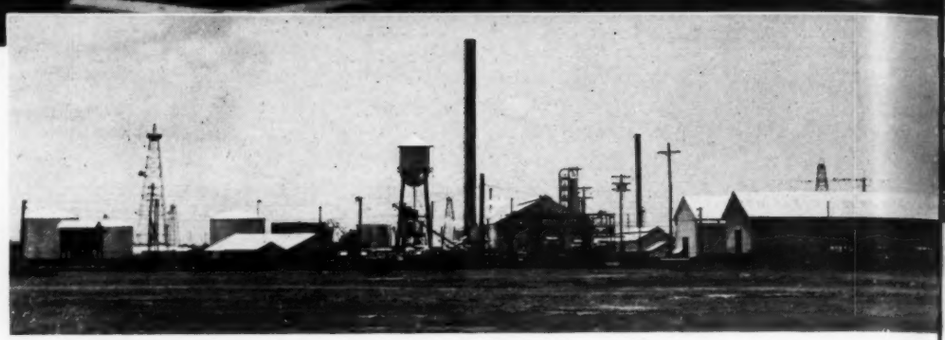
During the entire war period refinery development in countries not directly involved in the struggle has remained at a standstill. New equipment that normally would have been installed has been unobtainable and many plants have become completely obsolete by today's standards. The demand from every part of the oil world for machinery to rehabilitate existing plants or to equip new ones has become insistent.

From end to end of Latin America the need for new processes and machinery is emphasized. Mexico has one new plant well under way and proposes to modernize its whole refining industry with new refineries in several locations to meet its rapidly growing domestic consumption of oil products. In Venezuela four entirely new refineries are in more or less advanced steps of planning. It is reported that two new plants may be established if the early promises of newly developed fields are realized. Bolivia proposes to replace its outdated plants with new ones of added capacity. Argentina has been suffering from a fuel famine for the past three years. The government owned YPF is unable to refine all its present production and proposes to add new plants as soon as materials can be obtained. This by no means exhausts the list of Latin American countries interested in refining operations but indicates the extent of opportunities for equipment makers in this one important segment of the world industry.

Similiar conditions prevail in other parts of the world. In Russia the discovery of important producing, fields since the commencement of the war has resulted in a need for a number of up-to-date refineries, a need which the Soviet government is moving vigorously to satisfy. In Saudi Arabia a great new refinery is being pushed to completion to utilize the rising output of that oil-rich land. The doubling of existing capacity of the Iraq pipe line which is expected to be put under way by the end of the current year will make necessary the enlargement of the Haifa refinery or the erection of a new plant elsewhere. The whole post war refining picture foretells a period of activity in refinery building that has not been equaled even during the feverish preparation to meet the war situation.

Except for one fact the prospect might create uneasiness in oil industry circles because of the possibility of an oversupply of refining capacity during the early years of the post-war period. The limiting factor is the inability of existing engineering and manufacturing resources to satisfy this combined demand in less than several years. Working at top speed it will tax available resources in this particular field to complete the projects already planned within the coming decade.

A Glimpse of Abadan.



Above: Puerto la Cruz, Oil Shipping Port and Site of Future Refineries.
Right: Gasoline Plant of Gulf Company at Mene Grande Near Lake Maracaibo.

VENEZUELA'S AMBITIOUS REFINERY PLANS TAKING FORM

By Ruth Sheldon

Plans Have Been Drawn by Principal Operating Companies for Plants with Capacity of 145,000 Barrels Daily Under Agreements Signed with the Government — Construction Will Begin When Materials Become Available

WITHIN the next six years Venezuela will become a considerable factor in the world refining picture with the construction of a minimum of 145,000 barrels of modern refining capacity producing quality product from aviation gasoline to high grade lubricating oils. Plans are being made for four refineries to be built by Creole (Standard Oil Company, New Jersey), Sinclair Refining Co. of Venezuela, Caribbean (Shell) and Mene Grande (Gulf). Heretofore, Venezuela's refining activities have been of the simplest, confined primarily to supplying domestic needs, with the exception of lubricating oils which have been imported. During the war the minor existing facilities have been somewhat expanded to increase Diesel and fuel oil production.

The new refining capacity will come too late to assist in the prosecution of the Pacific war, but due to the shift in war theaters the increased refining capacity installed elsewhere in the Caribbean and operating on Venezuelan crude is proving of great benefit at the present time. In 1943 the Sinclair company applied for priorities to construct a 35,000 barrel refinery to produce 100 octane gasoline, toluene, Navy fuel oils and lubricating oils for the war program, but these priorities were not granted. The company has been forced to wait until materials were available and recently has signed an agreement with Venezuelan government to construct by January 1, 1951, a modern refinery based on peacetime requirements, of the same capacity. Land has been purchased at Puerto la Cruz, the terminal of the Sinclair 70,000 barrel capacity pipeline from its eastern Venezuela Santa Barbara field.

Puerto la Cruz, largest natural harbor on the northern coast of South America, is ideally located and has every natural advantage for the development of a port through which eastern Venezuelan commerce will flow as the potentially rich area is exploited for agriculture and industry in addition to oil.

The Sinclair Company plans include a model refining city. Particular attention will be paid to attractive housing for workers, following the plan inaugurated at the Sinclair Santa Barbara camp which provided houses of individual design rather than the sterotyped rows of identical houses, which has been the customary foreign oil camp formula.

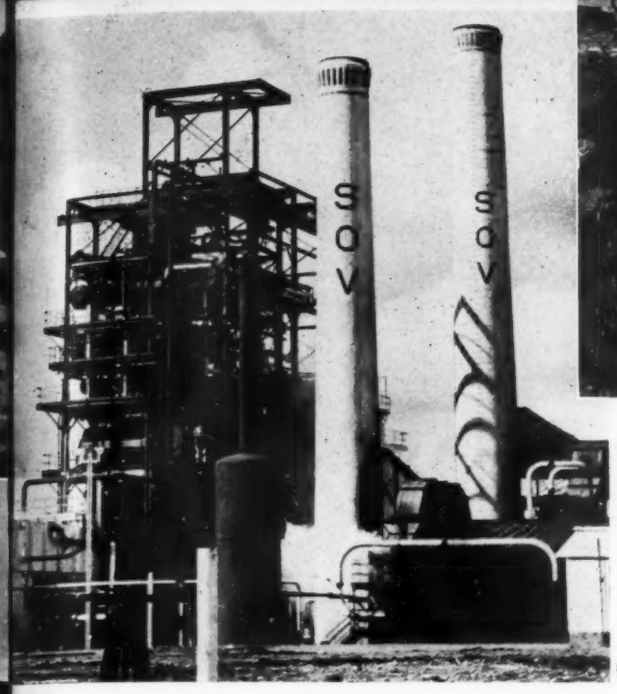
Construction of these new Venezuelan refieries will be a novelty in refining history. Heretofore refinery construction has always been a rush job, under pressure, without sufficient time for functional planning of houses, schools, hospitals, offices and recreational facilities as a unit with the refinery proper. These have usually been after-growths, sometimes less advantageously located than would have been possible if they could have been included in the original plans.

It is expected that refinery equipment will be available in the very near future and that orders placed now may be filled during the coming year. However, equipment will not be forthcoming in such quantities or at such times as to make rapid construction possible. Consequently, not only can functional designing of the refinery and its necessary adjuncts be achieved but also a reduction in construction cost. For example, permanent docks at the harbors can be built first and used for importation of equipment. Initial building of permanent houses for refinery workers will solve the housing problem for construction workers.

Creole plans to contract the functional planning of its refinery city to an architectural firm so that its refinery will be a show-place. Although its refinery agreement with the Venezuelan government is for 40,000 barrels capacity it plans an additional 10,000 barrels, with an ultimate expenditure of $50,000,000. In this event it will consolidate its small 8,000 barrel unit now operating at Las Salinas on Lake Maracaibo with the new refinery. It will continue to operate its Caripito refinery in eastern Venezuela, with a present capacity of 38,000 barrels, thereby bringing its total Venezuelan refining operations to well over 90,000 barrels daily.

In order to have trained workers available for the new refinery, which will employ approximately 1,600, Creole at present is deliberately double-staffing its Caripito and Las Salinas units. In addition, it is bringing Venezuelan engineers to the United States for advanced technical training, a procedure which the Sinclair company also plans.

Creole expects to break ground in the construction of workers' houses by the end of this year



Above: San Lorenzo Refinery of Shell in Western Venezuela.

Left: Standard Refinery at Caripito.

Right: Caripito Village and Terminal.

and to have the refinery completed by 1947. The refinery will produce aviation gasoline and also high grade lubricating oils for the export market. The refinery will run principally heavy lake crude as Creole's light eastern Venezuelan crude is easier to sell in the world market. Also Creole's lake reserves are three times larger than its eastern Venezuelan reserves.

The refinery will possibly be located at Turiamo, in the middle of the Venezuelan coastline, just north of Lake Maracay. General Juan Vicente Gomez, long time Venezuelan dictator, once envisioned this as the great port of Venezuela, built a road from Maracay and had a modern concrete dock built at the harbor, which has never been used. Second only to Puerto la Cruz in natural facilities and size it would provide an excellent location. Creole is considering the purchase of federal lands surrounding it, with privileges for the harbor's use. It is understood Creole would build a $4,500,000 road from Lake Maracaibo east over the coastal range to provide a major link in the trans-Venezuelan highway.

No pipeline would be contemplated at present, as the war-increased lake tanker fleet is ample to economically supply the refinery with crude for some years to come. In the future a pipeline project might be feasible, particularly if Creole discovers oil in its holdings south of Turiamo in the state of Guarico. However, if engineering difficulties are encountered and other factors do not favor this location, the refinery will be located at Puerto la Cruz.

In 1943, Caribbean (Shell) signed an agreement with the Venezuelan government to construct a 40,000 barrel refinery within five years following the end of the war, or five years from the time materials should become available. The refinery site selected is in the southwestern part of the Paraguana peninsula, east of the Gulf of Maracaibo, at a place near Punta Cardon. The plant, estimated at a cost of well over $35,000,000, will have ample cracking and auxiliary facilities, including provision for manufacture of aviation gasoline and lubeoils. Plans are being made for terminal loading facilities, employees' housing, hospital, sports ground and other facilities for the comfort of workers. Preliminary survey work has already begun and work on temporary camp facilities will start as soon as materials are available.

The fresh water problem on the Peninsula is severe and it has been estimated that Caribbean will have to build a 150-kilometer 12-inch water line to assure an ample year round water supply.

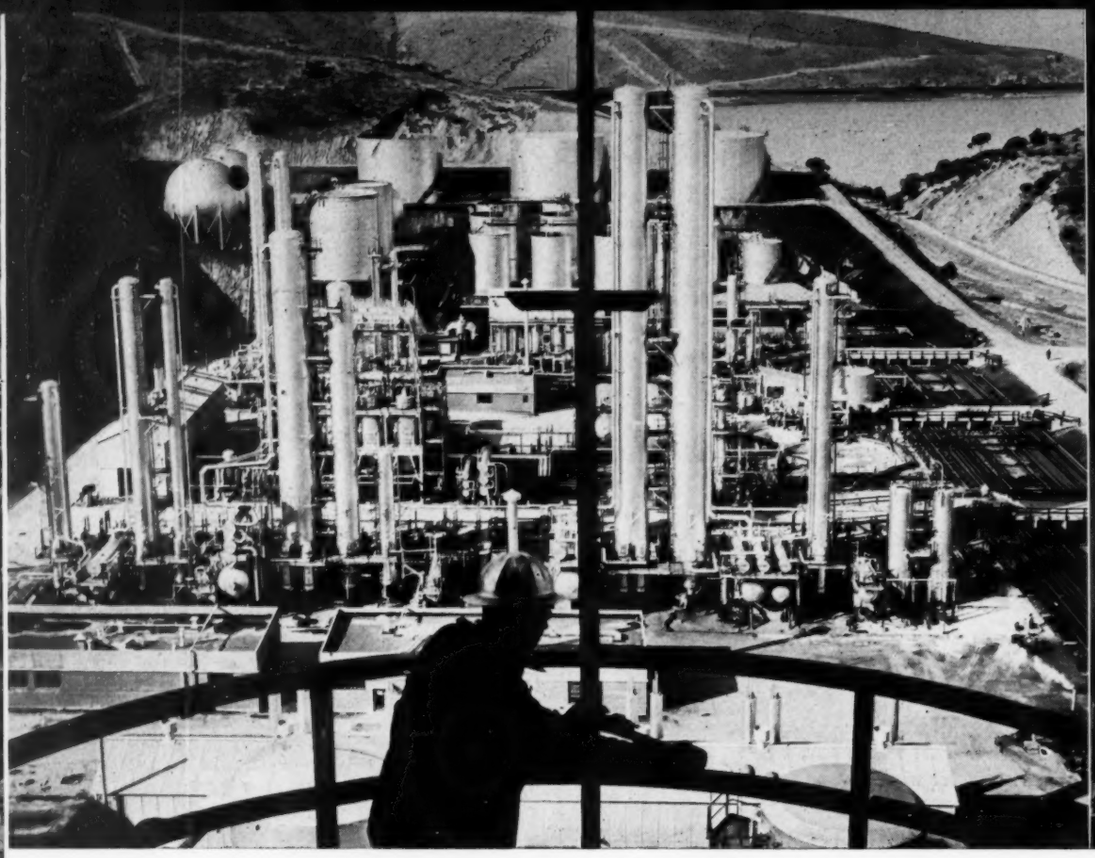
Gulf's refinery agreement with the Venezuelan government is for 20,000 barrels capacity, which will probably be located at Puerto la Cruz as a site for just such a purpose has been held for a number of years at the Gulf terminal there. Gulf's plans are still in the preliminary stage, although the refinery must be completed by January 1, 1951.

In addition to these four refineries Venezuela may ultimately have one or two more. Both Socony-Vacuum and Texas companies have refining agreements with the government for 20,000 barrels capacity each as their production reaches a stage to justify it. Newcomers such as Phillips, Barnsdall, Standard Oil of California and Atlantic have been granted concessions under the new petroleum law which requires that a minimum of 10 percent of their production must be refined within the country. In consequence, if their production warrants, these companies may combine to build one or two more refineries.

Venezuela's debut into the world refining picture is a political triumph for the government rather than a natural economic development and will pour balm upon the irritation caused by the presence of great refineries on the little Dutch islands of Aruba and Curacao just off Venezuela's coastline. These refineries, one owned by Jersey Standard and the other by Shell, handle the greater part of Venezuelan crude and Venezuela has long resented the fact that it does not receive revenues from these industries and that the 9,800 workers are not Venezuelans.

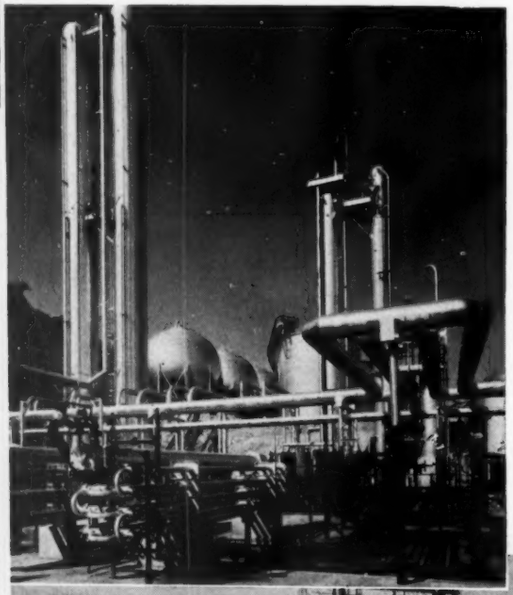
When the 1943 petroleum law was inaugurated, President Medina promised the people something would be done to obtain for Venezuela its refining rights, as it considered them. The refining agreements of the various companies already referred to were the result. Concessions granted under the new law carry the provision that any oil exported from Venezuela cannot be refined within a zone bounded by the Tropic of Cancer, the Equator and meridians 50 degrees and 90 degrees—a zone which very successfully includes Aruba and Curacao. This provision and the projected construction of new refineries presage an uncertain future for Aruba and Curacao—at least as far as Venezuelan crude is concerned.

Entrance of Venezuela's new 145,000 barrel capacity in an increasingly nationalistic world where consuming countries want to manufacture products rather than import them poses a marketing problem. Venezuela's products may face difficulty in entering some of their former markets if this policy is generally adopted. At the same time, the Venezuelan government has the obligation to see that its infant industry is not stillborn due to excessive taxes, port fees, and other charges, for its products must always compete with those of the United States and the Middle East.



CALIFORNIA REFINERIES PLAY IMPORTANT PART IN FUELING WAR OPERATIONS IN THE PACIFIC

Left: General View 100-Octane Plant, Richmond Refinery.
Above: Hydrofluoric Acid Alkylation Unit.
Below: Alkylation Plant in Foreground — Thermal Crackers in Background.

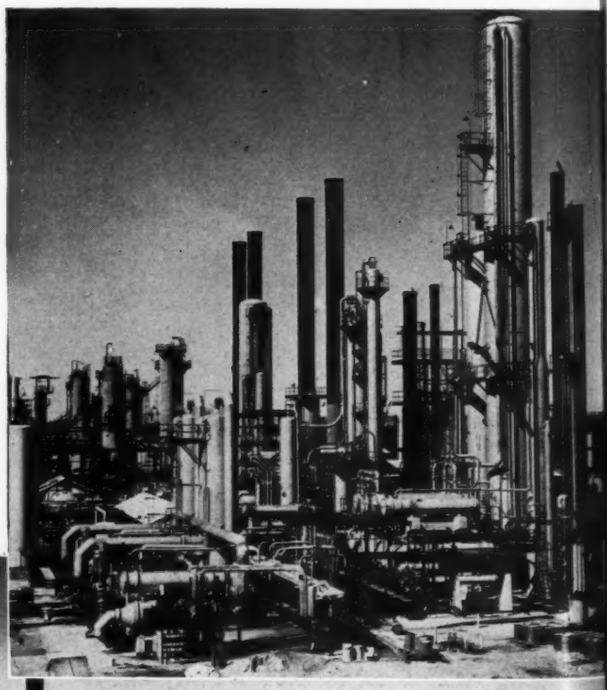


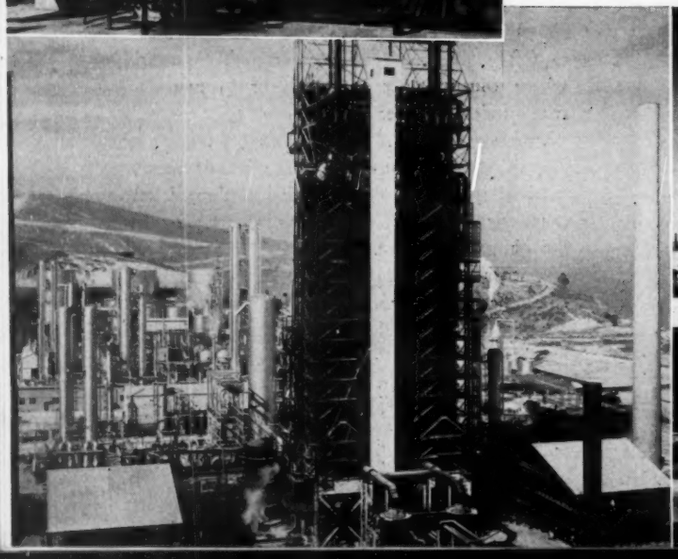
Strategic Location of Coast Plants Has Led to Great Expansion of Capacity for Making of Products for Military Use in Anticipation of Present Concentration of War Activities in the Asiatic Theatre.

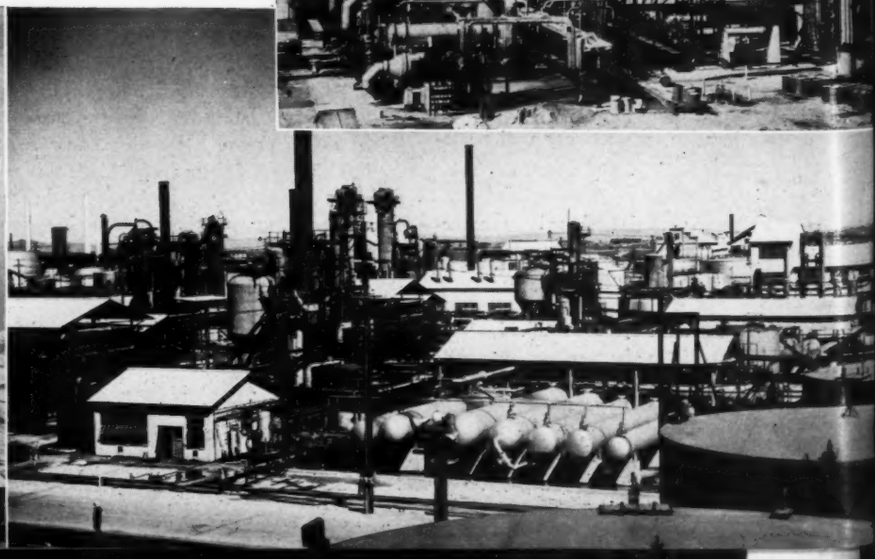
Left: Butane-Pentane Distillation Unit and Storage Tanks.

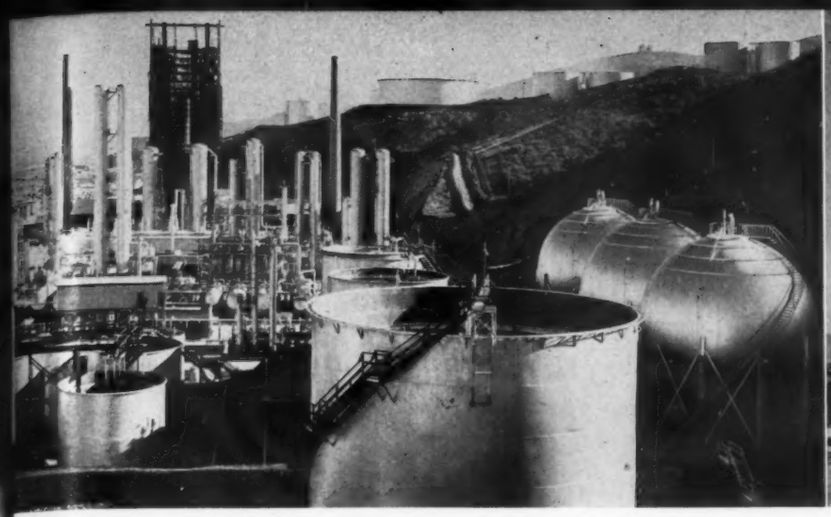
Lower Left: 100-Octane Plant and TCC Unit.

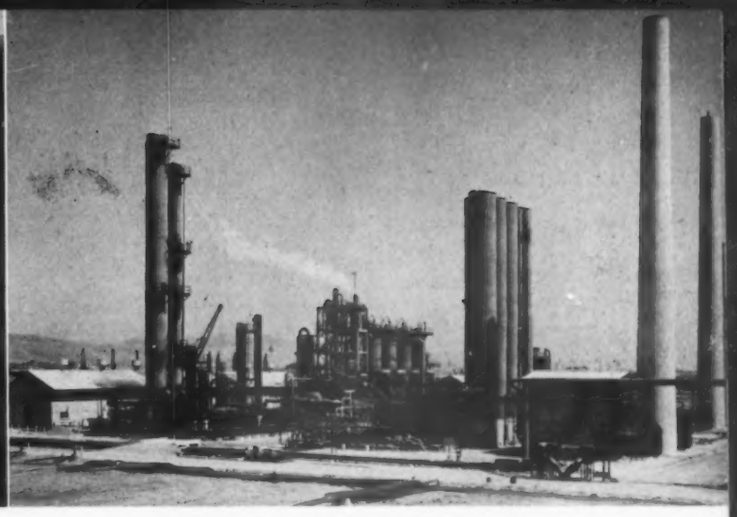
Lower Right: Lubricating Oil Refining Plants with Extractors of #1 Solvent Plant in Foreground.











Above: Toluene Plant, Richmond Refinery.

Left: View of New 100-Octane Plant Nestled in the Hills Bordering San Francisco Bay.

WITH the concentration of war activities in the western ocean Pacific Coast refineries, because of their strategic location, occupy a place of special importance in producing petroleum products to hasten the coming of V-J day. In anticipation of this situation the capacity of California refineries for the production of high octane aviation gasoline and other special products for military use has been greatly enlarged. In the pre-war period the crude supply from California wells was sufficient to keep the refineries in operation but today, despite the stepping up of well production to near the million barrel a day mark crude is being brought into the state in growing quantity for processing close to the shipping ports through which it is desirable to move as large a volume of war material as possible.

Some unusual conditions have resulted from the pressure to meet military demands. As an example the small refinery of Standard Oil Company of California at Bakersfield which has been making gasoline for the local use of San Joaquin Valley motorists for the past thirty-two years, is now devoted exclusively to the manufacture of high octane aviation fuel. As a consequence the company has to move motor fuel from its El Segundo refinery by truck into Bakersfield, the greatest oil producing center on the Pacific Coast.

As the largest operator along the western littoral Standard has been called upon to take a leading part in providing products for military use. Its Richmond and El Segundo refineries bristle with a combined total of $47,000,000 worth of new plants and facilities completed since the Japanese attack on Pearl Harbor. Of this figure $27,000,000 was financed by the government; the remainder represents company investment.

The largest producer of 100 octane gasoline in the West, Standard has already passed the billion-gallon mark. During 1941, with five percent of the nation's crude run capacity and three percent of its cracking facilities, the company was turning out 12.5 percent of the nation's 100 octane gasoline. Since Pearl Harbor, Standard has increased its production of this high-test fuel by approximately 475 percent.

A $20,000,000 Defense Plant Corporation 100-octane plant went on stream in January of this year at the companys' Richmond refinery on San Francisco Bay. Heart of the big plant is the Thermofor catalytic cracking and treating unit which towers 238 feet in the air — as high as the average 22-story office building. The "cat-cracker" is made up of essentially two units: one cracks gas oil feed stocks by means of a bead catalyst; the other upgrades the gasoline produced in the first operation by subjecting it again to the action of the catalyst. A train-load of more than fifty freight cars of bead catalyst was required to fill the plant. From the double treatment comes a stock that by itself is almost equivalent to final 100 octane in quality. However, this stock must be blended with others to make the final product.

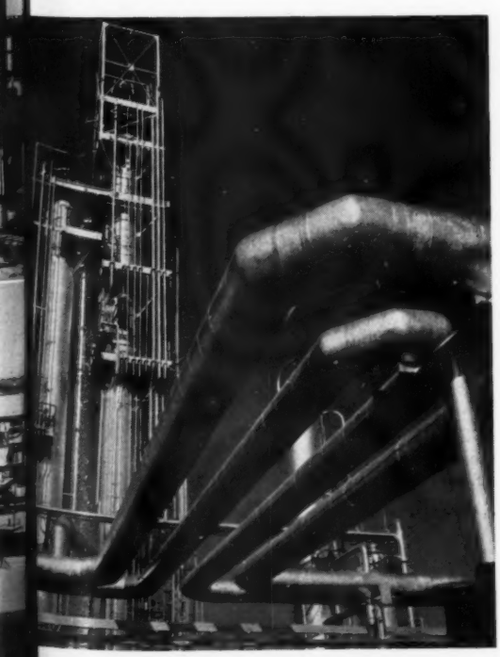
Two large furnaces are used to heat the oil feed to the reaction vessels. Each contains two fire-boxes and each of these is about the size of an average small house; 36 feet square and 16 feet high. Each furnace burns enough fuel in an hour to heat an ordinary seven-room house for a year.

The other major processes in the plant are: the butane isomerization unit, which converts normal butane into isobutane, a necessary component for the production of alkylate, a basic high octane blending agent; the hydrofluoric acid alkylation unit, which takes isobutane and other light hydrocarbon fractions and synthesizes them into alkylate. Virtually all the recoverable alkylation feed stocks produced in the entire Richmond refinery now are converted to high octane alkylate, which accounts for the large quantity of 100 octane produced from each barrel of crude.

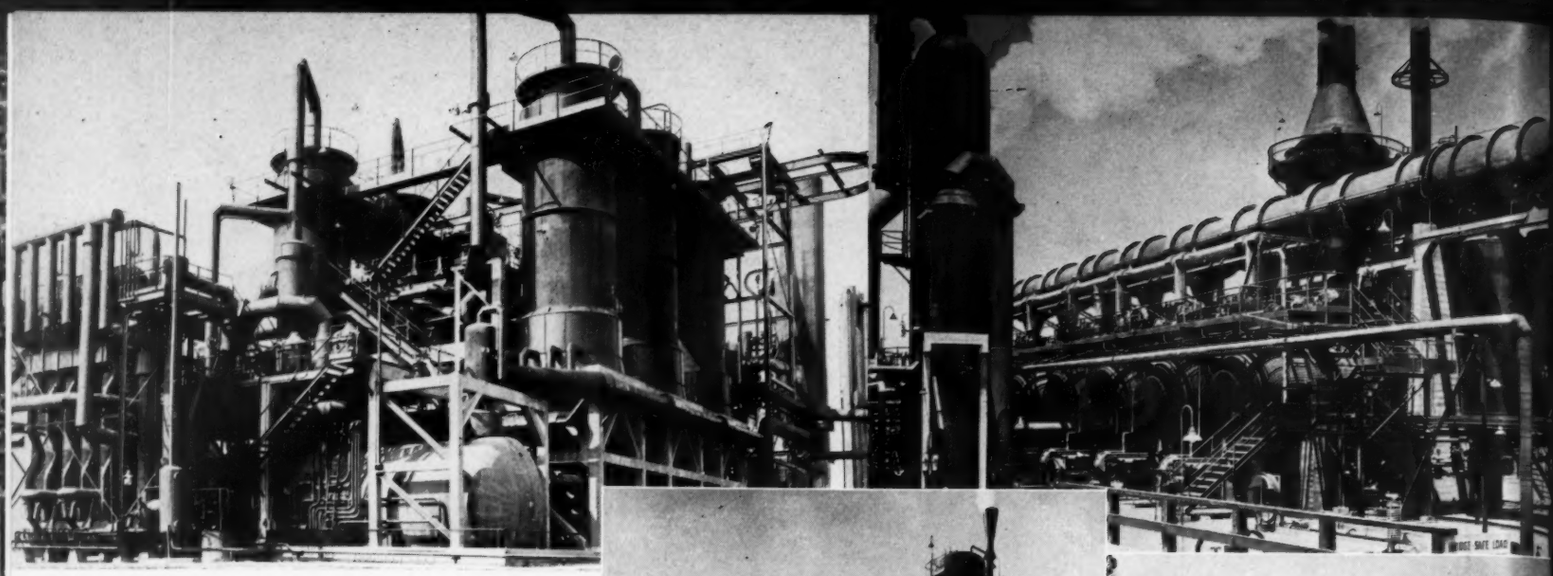
Because of the properties of hydroflouric acid only trained workmen in specially-made coverall suits or jackets and face protectors are allowed to work in this unit. The suits are made of special synthetic rubber and give their wearers the appearance of the popular conception of "men from Mars". Distillation equipment for rejection of normal pentane permits removal of low octane normal pentane from base stocks to upgrade them for subsequence use in 100 octane blending.

Standard is operating the 100 octane plant under lease agreement with Defense Plant Corporation. Equipment process designing, with the exception of the catalytic cracker, was handled by the California Research Corporation, a subsidiary of Standard of California. The cat cracker was designed by the Bechtel-McCone Corporation. Apart from the 100 octane plant at Richmond is another alkylation plant completed in January 1941 at a cost of $910,000. This unit turns out 100 octane gasoline base stock by processing propylenes, butylenes, pentenes, codimers and isobutane with sulfuric acid. Adjoining this plant are five thermal crackers the last of which was completed in July 1942. In these units, reduced crude is processed into gas fractions for sulfuric acid alkylation plant feed stock, as well as into motor gasoline and fuel oil. According to PAW, more fuel oil will be needed in the war against Japan than was required for both war fronts before Germany was defeated. The initial landing on Okinawa took 600,000,000 gallons of fuel oil.

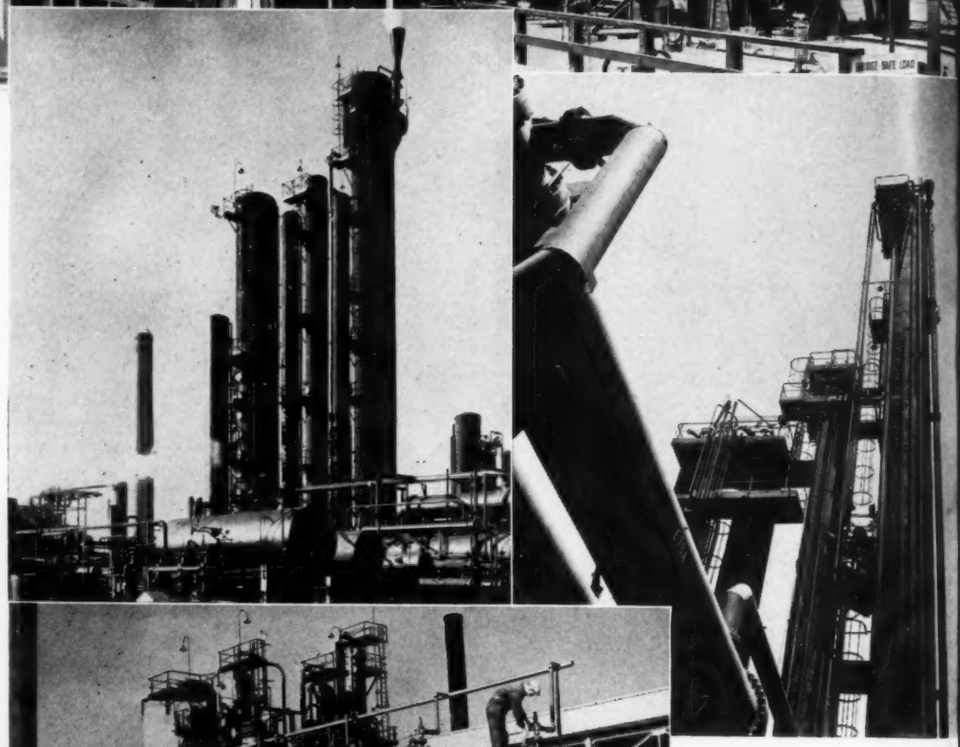
In cooperation with the Navy, Standards' research subsidiary has provided a special ingredient

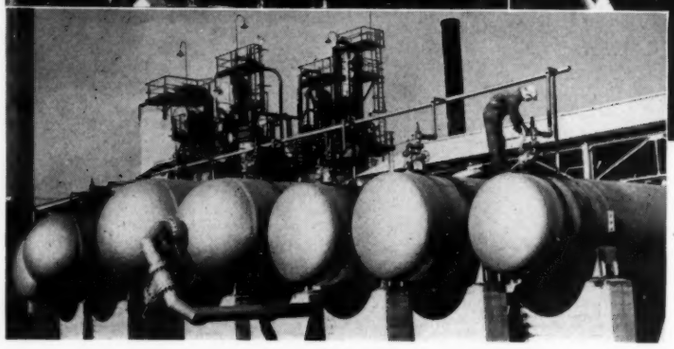


Butane Isomerization Unit.



Houdry Aviation Gasoline Plant, El Segundo.





Top Right: Reactor Section of Butadiene Plant, El Segundo.

Above: Angle View of Isomerization Plant, El Segundo.

Center: Extraction and Absorption Columns, El Segundo.

Left: RPM Solvent Treating Plant, Richmond.

making possible the manufacture of a compounded high cetane Diesel fuel for civilian use and has also made this ingredient available to others in the petroleum industry. This additive has permitted Standard to make available its entire production of natural high cetane Diesel fuel for the Navy. Subsequently, the company has led in western production of high cetane Diesel fuel for the Navy and essential war industries.

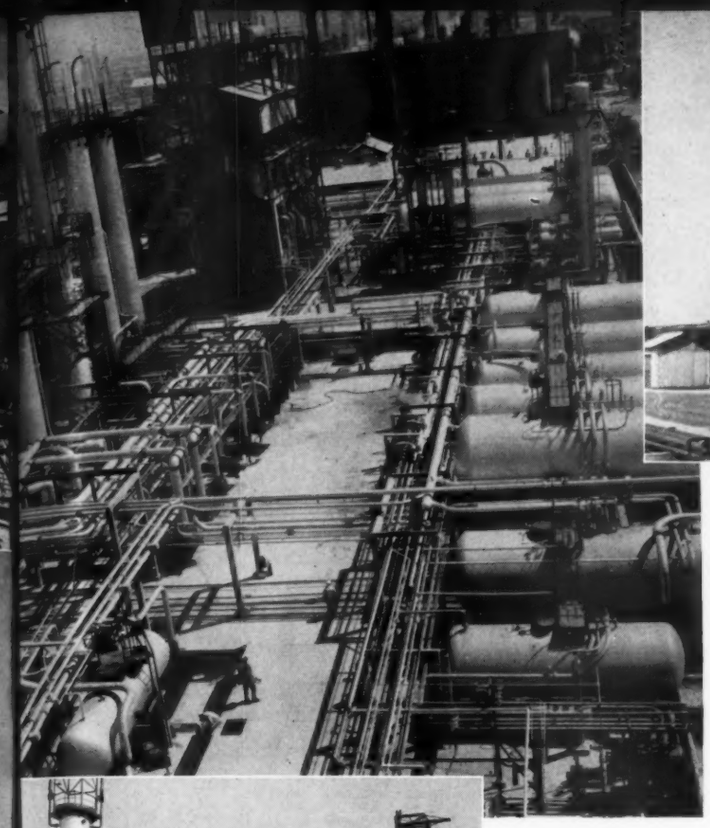
One of the most interesting war plants at Richmond refinery is the "dual-purpose" $10,000,000 toluene plant completed in February 1943. It was designed by Standard engineers so that it can produce either toluene or high octane aviation gasoline, and the switch from one product to the other can be made without even a shutdown, as the demand warrants. The plant employs the latest catalytic method of producing toluene out of straight run naphtha from crude stills. It is the only single installation in the country capable of completing by catalysis the entire process of producing pure toluene. The catalyst, developed by Standard of California, is now being manufactured for the majority of the synthetic toluene plants in the United States. The process consists of heating the feed stock under high pressure to approximately 1000 degrees F, bringing the vapors in contact with the catalyst, and then passing the stock through four distillation units to concentrate the toluene content. High octane gasoline is produced by much the same method.

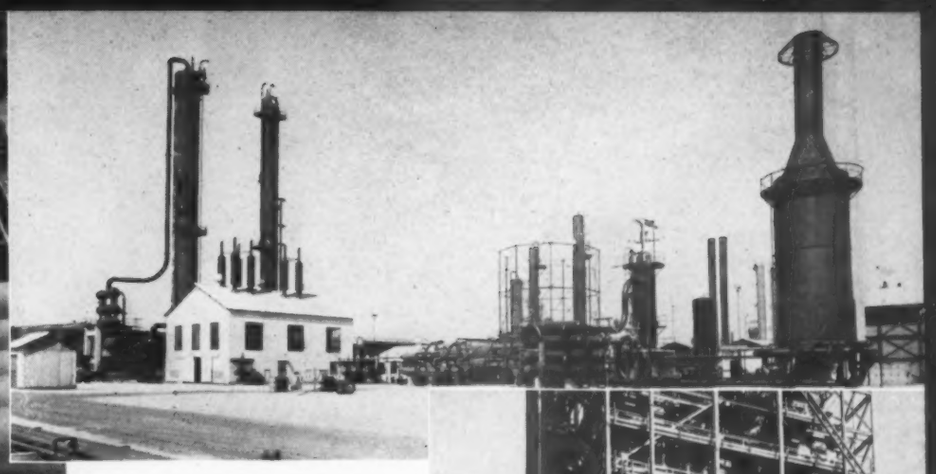
A pioneer in the development of compounded lubricating oils, Standard has invested more than $5,000,000 in lubricating oil plants at Richmond since the war started. These compounded oils, which combat the formation or accumulation of gum and carbon deposits, have been particularly useful in the operation of high-speed Diesel engines. They are not only extremely stable and resistant to oxidation, but they also have cleansing properities.

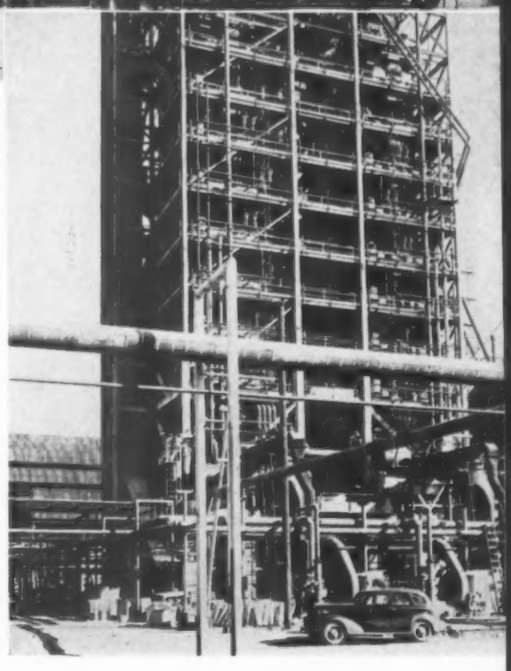
The performance of Standard's "RPM Delo" under severest operating conditions has been so outstanding that both the Army and Navy used it as a pattern for specifications. This oil has greatly reduced maintenance difficulties of submarines and other vessels and has enabled them to extend their cruising ranges far beyond previous limits. The oil also has played an important role in the performance of tractors, trucks and similar heavy duty military and industrial equipment. Richmond refinery employees, more than a quarter of whom are women, have achieved a war production record during the past three and a half years that has brought the refinery five Army-Navy "E" awards.

Equally busy turning out war products is Standard's refinery at El Segundo in southern California. Here the West's first catalytic cracking plant was completed in September 1942. Designed originally for the production of high quality motor gasoline, this Houdry plant was converted before initial operation to produce a maximum of base stock for 100 octane gasoline. The change-over was accomplished by the adaptation of existing facilities and with a minimum of additional equipment.

A year later an isomerization plant, designed by company engineers, was completed at El Segundo. This unit converts normal butane into isobutane for use as feed stock in the alkylation plant. PAW, in a recent letter to Vice President Davidson, praised the El Segundo refinery





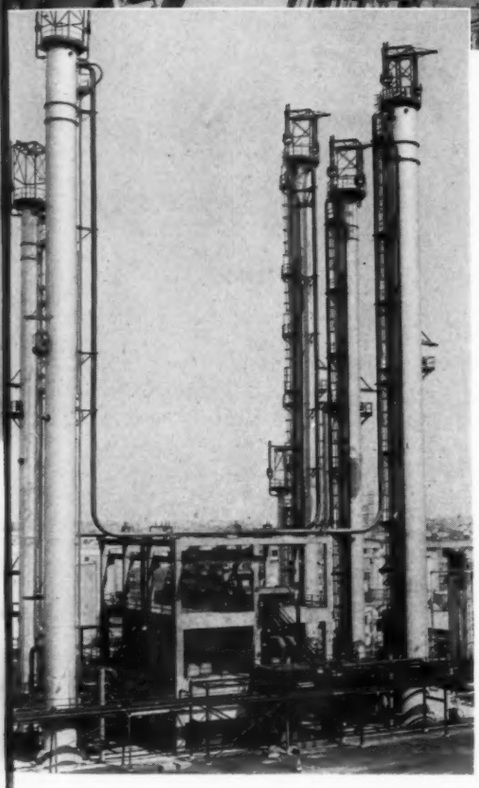


Above: Catalytic Hydrogenation Plant, Wilmington-Dominguez Refinery.

Left: Alkylation and Isomerization Plants, Union, Wilmington.

Lower Left: Superfractionator, Texas Company's Los Angeles Works.

Right: Two Eight Section Thermofor Kilns of Double TCC Unit, General Petroleum, Torrance.



by augmenting refrigeration facilities with equipment purchased from an ice rink.

Raw material for synthetic rubber is manufactured at the El Segundo refinery in the butadiene plant, completed in February 1944. It was designed and built for Defense Plant Corporation and is operated by Standard for Rubber Reserve. Enough butadiene for the manufacture of four million automobile tires can be produced annually by this plant.

The process involves catalytic dehydrogenation of normal butane, first to butene and finally to butadiene. Selection of the process employed was influenced materially by the desire to avoid any interference with the production of aviation gasoline. In this process, normal butane is dehydrogenated to butadiene, part to butene, and some is converted to coke and light gases during the first pass through the catalyst. The butadiene is recovered from the reaction products after removal of the light gases, and the remaining butane-butene mixture is routed back through the catalyst for further conversion. All the normal butane fed to the plant, therefore, is recovered as butadiene or appears as coke or as light gases which are used as fuel.

The coke produced by decomposition reactions is deposited on the catalyst and is burned off at regular intervals by admitting air to the catalyst chambers. Alternate dehydrogenation and coke burning periods are automatically controlled by an electrical cycle timer, because the frequency and complexity of the operations are such that manual control is not feasible. Hot combustion gases leaving the catalyst chambers are passed through a bank of ten waste heat boilers where the heat is recovered by generating steam, which in turn is used in operation of the plant.

Butadiene is recovered from the products of dehydrogenation by solvent extraction. Because of the ease with which butadiene combines itself to form heavy liquids or solid materials, it is necessary to add small amounts of a chemical which inhibits polymerization if the butadiene is to be stored for more than several days. The inhibitor is added to each tank of product as it is produced.

A unique feature of the process is that operations are so conducted that the heat absorbed during the dehydrogenation essentially balances the heat liberated during the coke burning period. In this way, equipment required for adding or removing heat from the catalyst is largely avoided.

In the field of petroleum chemistry, a new million dollar plant has just been completed by Oronite Chemical Company, a Standard of California subsidiary, at the Richmond refinery. This plant, first of its kind west of St. Louis, is manufacturing phthalic anhydride, basic stock for alkyd resin paints and finishes. Such paints, which now go almost exclusively to war uses, are expected to play an important part in the post-war building construction field. They are more durable than pre-war paints and are

for its output of isobutane saying, "The production rates of the isomerization units have been consistently outstanding and represent a highly commendable achievement".

The alkylation plant, constructed before Pearl Harbor, has since upped production five-fold through additions costing only about half the original plant investment. Also, methods have been developed for improving the performance of almost all the equipment in the layout. The capacity of the plant has been increased

resistant to deterioration caused by sun, heat and moisture. They work even better on metal than on wood. The Navy has found them highly resistant to salt spray and extreme changes in temperature.

Phthalic anhydride has a variety of other possibilities. Currently, it is being employed as the "starting material" for the manufacture of one of the new-type insect repellents which have been so important in maintaining the health of American fighting men in the South Pacific. Studies are being made to extend its uses to other chemical fields.

With very few exceptions, all Standard's plants completed since Pearl Harbor have greatly exceeded their original design capacities. This has been accomplished by ingenious rearrangement of facilities and careful examination of all operations to make sure that every ounce of usefulness is squeezed from each barrel of crude oil. In the words of G. A. Davidson, vice president in charge of manufacturing, "Good operators with a will to do so can make any plant exceed its nominal capacity when supported by ingenious designers."

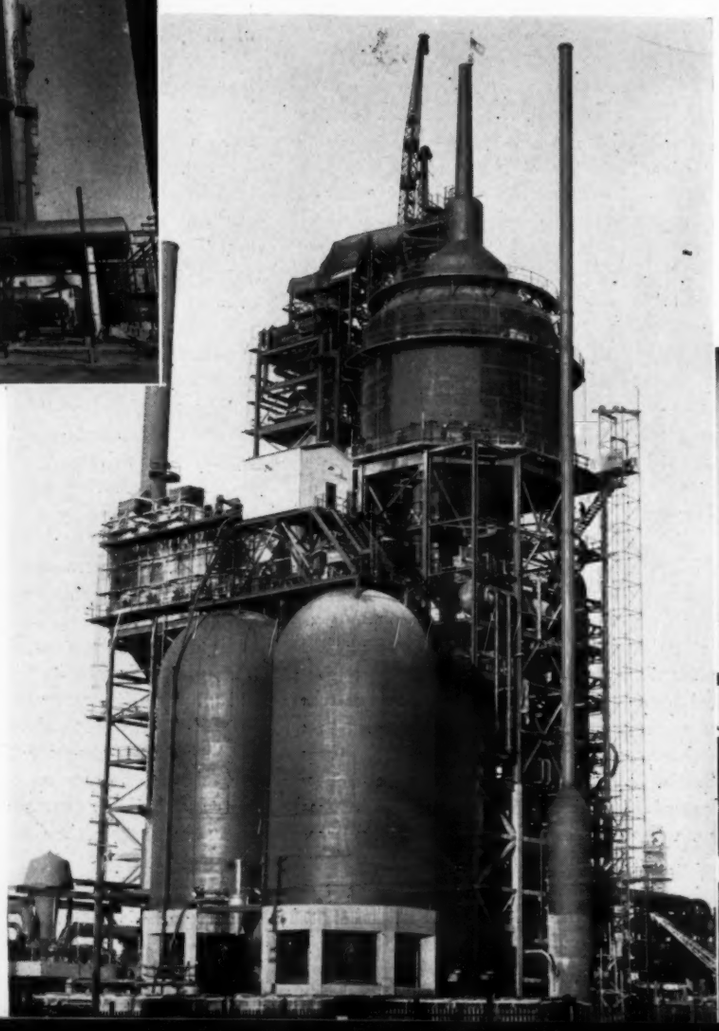
An important factor in enlarging the Pacific Coast output of petroleum products for war are the units installed in the great Avon refinery of Tide Water Associated Oil Company. This is one of the few plants in the country that was producing alkylate before the start of the war. A sulphuric acid alkylation unit was built in 1940 and this was expanded by successive extensions in each of the following four years. A pentane isomerization unit was added in 1944 and the group was rounded out by the completion at the end of last year of the world's largest single fluid catalytic unit with a charging capacity of 16,000 barrels per day of gas oil. A number of new features incorporated in the design give it a high degree of flexibility and enable it to utilize a wide variety of feed stocks. The process employed in the cracking unit is licensed by Universal Oil Products Company and was designed by engineers of that company in cooperation with the engineering staffs of Tide Water Associated and the C. F. Braun Company.

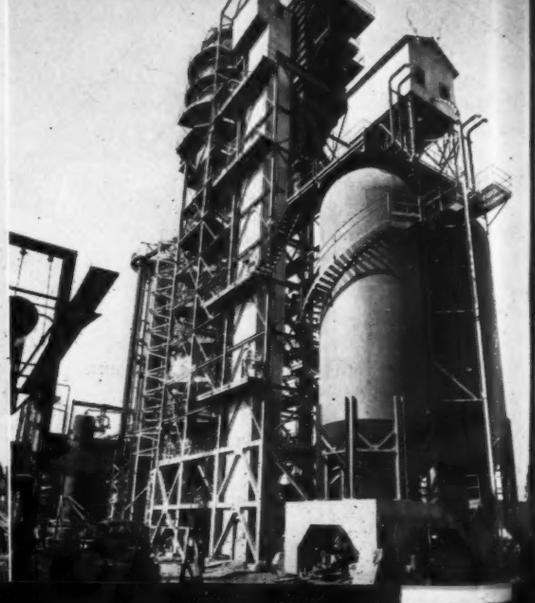
A very complete plant for the production of aviation gasoline and toluene is that of Shell Oil Company at Wilmington, California. The installation for 100 octane production includes a feed preparation plant, product fractionation equipment, an alkylation plant, three butane isomerization units and a fluid catalytic cracking unit. The toluene production section consists of five units: prefraction, isomerization, dehydrogenation, extractive distillation and catalyst manufacture. At Martinez the Shell Chemical division of the company operates another large toluene plant employing special processes developed by the company.

Through expansion of its Wilmington refinery by the addition of several units, including combination cracking, TCC, alkylation and isomerization, Union Oil Company is converting Los Angeles basin crude and gas oils into products for military use. Among these are aviation and special government gasolines, Diesel and fuel oils.

General Petroleum Company has developed at Torrance, California, a plant of large capacity which includes an alkylation section and four TCC cracking units. Two of the units crack gas oil and the other two process the catalytic gasoline products. The H. F. alkylation unit produces either butylene, amelene or a mixture of butylene and amelene alkylate.

At Watson, California, the Richfield Oil Company has constructed a thoroughly complete and up-to-date plant which includes three alkylation units, isomerization and fractionation installations and a TCC cracking plant which produces a large volume of 100-octane gasoline and components from reduced crude, heavy and light gas oil, distillate and normal butane. Other California plants contributing importantly to the supply of fuels for war use are those of Wilshire Oil Company at Norwalk and Mohawk Petroleum Company at Bakersfield. The former includes in addition to a fluid catalytic cracker, an isomerization unit, an alkylation plant and a UOP cumene process, and the latter is equipped with alkylation and isomerization units built in 1944. These and other California plants which supply base stocks and components of 100-octane gasoline are enabling this Pacific Coast state to carry a substantial part of the load in fueling the planes, ships and mechanized equipment that are forcing Japan toward the inevitable capitulation that will end the war.



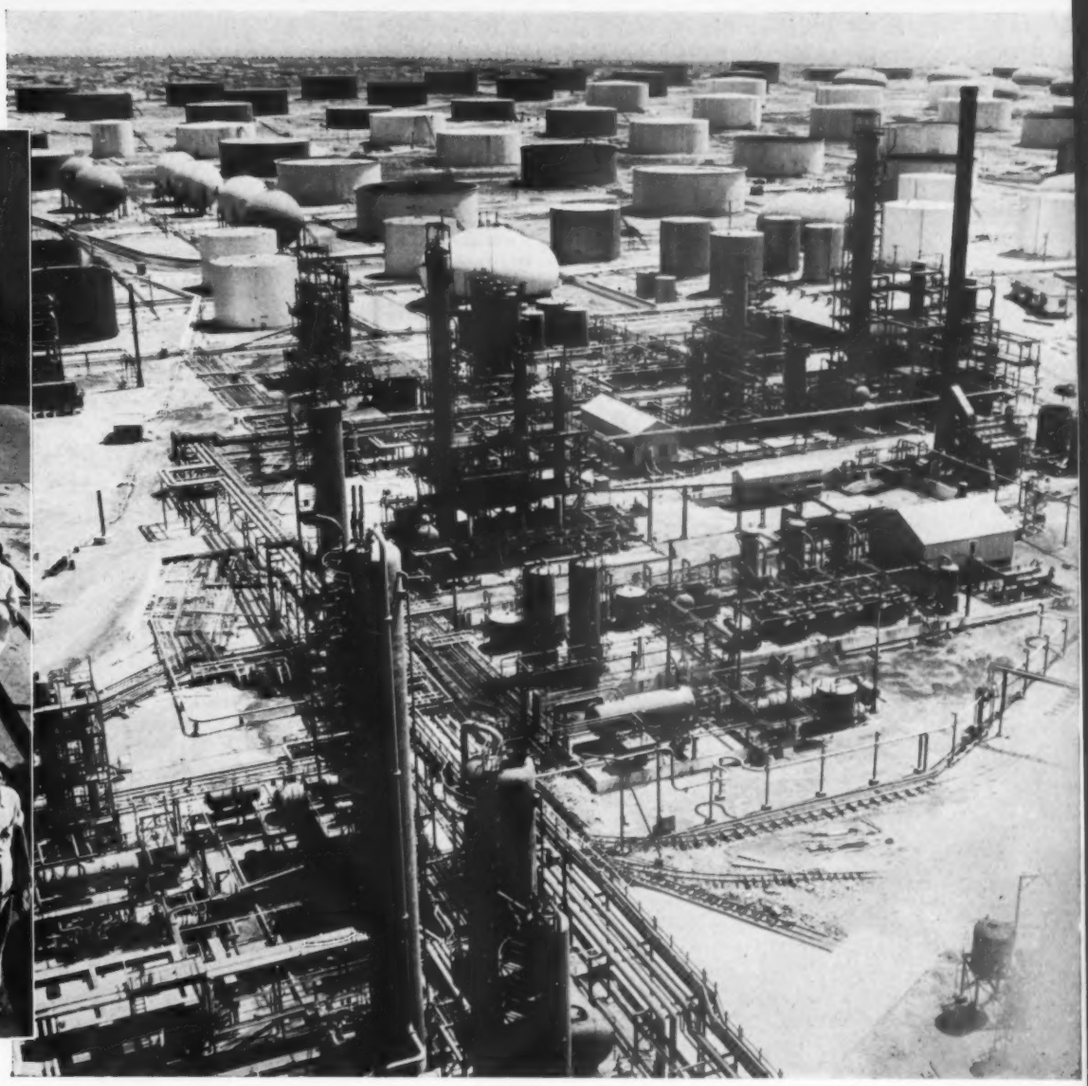


Above: Extraction Unit, Shell, Los Angeles.

Right: Tide Water Catalytic Cracking Unit, Avon.

Extreme Right: Fluid Catalytic Cracker, Wilshire, Norwalk.

7,000 Employees Fill Refinery Street at Shift Changes.



Elevation View of Refinery and Tank Farm.

HOUSING $81,000,000 WORTH OF EQUIPMENT

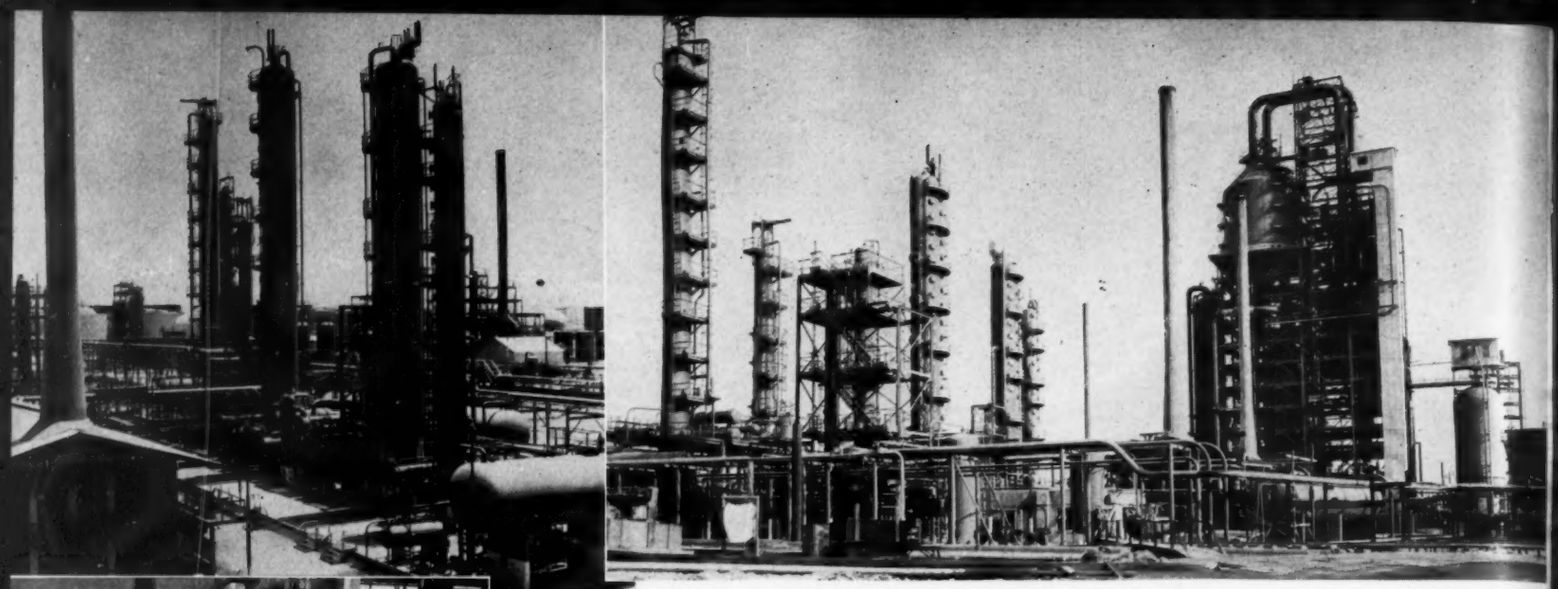
Aruba Refinery Is Large Producer of War Supplies

Despite Enemy Shelling, Long Blackout and Transportation Difficulties Island Plant Has Been Greatly Enlarged to Increase Output of Products for Military Use—Processed Billionth Barrel of Crude in March 1945.

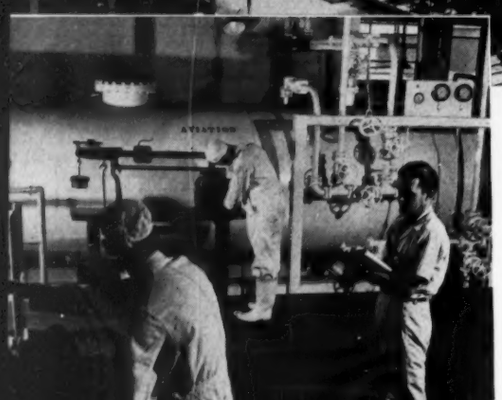
THOUGH surrounded by a sea accessible to hostile submarines that separated it from its source of petroleum supply and from the source of construction material throughout the war, the refinery of the Lago Oil & Transport Company, a subsidiary of the Standard Oil Company (New Jersey) on the island of Aruba, not only attained a daily output of petroleum products exceeding its peacetime peaks but also succeeded in erecting brand new units for making thousands of barrels per day of 100 octane aviation gasoline. The high refinery crude throughput was accomplished largely with existing facilities. Wartime construction, except for normal maintenance, was limited to equipment for aviation gasoline manufacturing processes.

With a crude running capacity of nearly 300,000 barrels per day just prior to the war, the refinery was generally regarded as the largest in the world. Early in the war, due to shipping difficulties, crude run was somewhat below this figure. However, a single day's through-put as high as 350,000 barrels was reached in May 1944. On March 15, 1945 the refinery celebrated the first billionth barrel of crude processed in its 16 years of operation. The refinery turns out all grades of aviation gasoline, motor gasoline, kerosene, Diesel fuel, distillate fuel oils, residual fuel oils, cutback asphalt, in large volume and a number of other products in small quantities. Lubricating oil stocks are exported for finishing. Practically all of the refinery's output has been used directly or indirectly for the war effort.

All of the refinery's operations are carried out on an area of less than one square mile—550 acres to be exact. In this small section are concentrated, besides the new aviation gasoline facilities, more than $81,000,000 worth of equipment. Items included in this equipment with the approximate full capacities in barrels per stream day indicated are as follows: an atmospheric pipe still of 16,000 B/D, a combination atmospheric and vacuum pipe of 28,000 B/D, four small crude stills of 8,000 B/D each, eight combination thermal units, four of 22,000 B/D and four of 25,000 B/D each, and three vis-breakers of 22,000 B/D each, four re-run stills and one two-stage gas oil cracking unit of 9,000 B/D capacity; an Edeleanu plant for upgrading kerosene; an acid treating plant and sweetening plants; a powerhouse; 200 tanks with an aggregate storage capacity of 13,500,000 barrels; and 2,500 miles of main distribution piping. Other equipment includes a 160 ton per day acid manufacturing plant that not only supplies the Aruba refinery but also furnishes sulfuric acid to the N. V. Curacaosche Petroleum Industrie Maatschappij on Curacao and a naphthenic acid plant that supplies a substantial proportion of the



"Cat" Cracker and High Octane Units.



Above: Light Ends Still and Furnace.

Left: Checking Mixture Weights in Ethyl Blending Plant.

United States' requirements of this product for the manufacture of vital war products.

Some time before the war the refinery was equipped with an aviation gasoline re-run still, a polymerization unit and a hydrogenation plant for the production of hydrocodimer, the principal aviation gasoline blending agent before the advent of the alkylation process in 1938. In 1939 the refinery was equipped with an alkylation unit. With these aviation gasoline facilities the refinery was in a position to supply the British with 100 octane aviation gasoline during the first two years of the war.

In December 1941 consideration was given to installing a 15,500 B/D charge capacity Fluid catalyst cracking plant in an aviation gasoline expansion program. To accomplish the program meant shipping to the island 35,000 long tons of material including associated operating units. Among items in the aviation gasoline expansion program were: a catalytic cracking unit with attendant fractionation facilities, a gas compression plant and gas scrubbing unit, a new alkylation plant, an isomerization unit, a low pressure gas collecting and compressor plant, a de-isobutanizer, a boiler and power plant, tankage and general facilities. Changes were also made in existing facilities to increase the recovery of reactive butanes.

Plans were started early in 1942 and by mid-1942 a preliminary shipment of such material as lumber and cement for the construction of foundations and housing was made. This shipment was lost due to enemy action. While the amount of material was not large its loss caused some delay in beginning the construction. Subsequently changes were made in arrangements for the shipments of cargoes and by operating in convoy under the protection of the Navy no further losses were incurred.

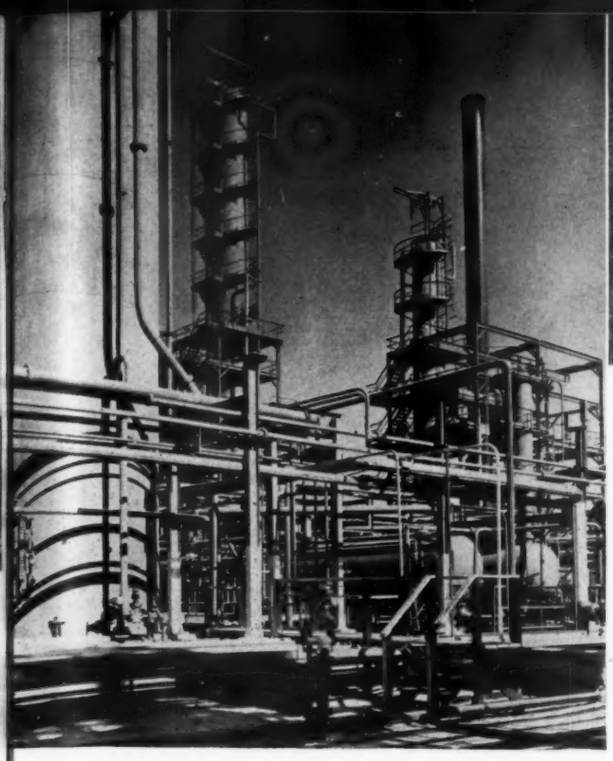
Much of the equipment was carried by Liberty ships on their maiden journey. Beside freighters, material was also carried by tankers, and a substantial amount of special smaller items of equipment was flown to Aruba by air, a large proportion by the K.L.M. air lines. Having to transport the construction material over long distances both by land freight and by sea necessitated fabricating much of it within the limits of handling ability. Large equipment such as towers had to be designed to fit the transportation means. Catalyst for the cracking unit was shipped in fibre drums, some 500 tons being stored at the refinery in an oil storage tank modified to handle it until the catalyst hoppers at the unit were ready to be filled. Altogether something on the order of fifteen to twenty million dollars' worth of equipment was transported. In the course of delivering the equipment more cargo was unloaded at Aruba in less time than ever before in the refinery's history.

Contractors supplied 400 men to supervise the construction, all of whom were flown to the island from the United States. Some replacements also were necessary to fill positions left by men who requested to be relieved. Aruba picked up labor from adjoining islands, most of the labor coming from the island of St. Vincent. Recruiting programs were organized in the various islands and the men transported to Aruba by schooners, one of which was sunk by submarines with some loss of life, and by other small boats. Eventually as many as 2,600 men were brought to Aruba, a considerable number of whom were rejected for physical or other unfitness, the largest number engaged on the construction at any one time being about 2,100. These were housed in a camp set up by the refinery on Aruba.

Delivery of materials and field construction work was pressed as much as possible. The work week consisted of six or seven 10-hour days and work was carried out at night whenever it could be arranged. Owing to the blackout conditions little work was possible at night for the greater part of the construction period. By special permission for a part of the time some illumination was allowed at night provided lights were not visible in the direction of the sea. To speed the construction, payment of considerable bonuses for overtime work was necessary.

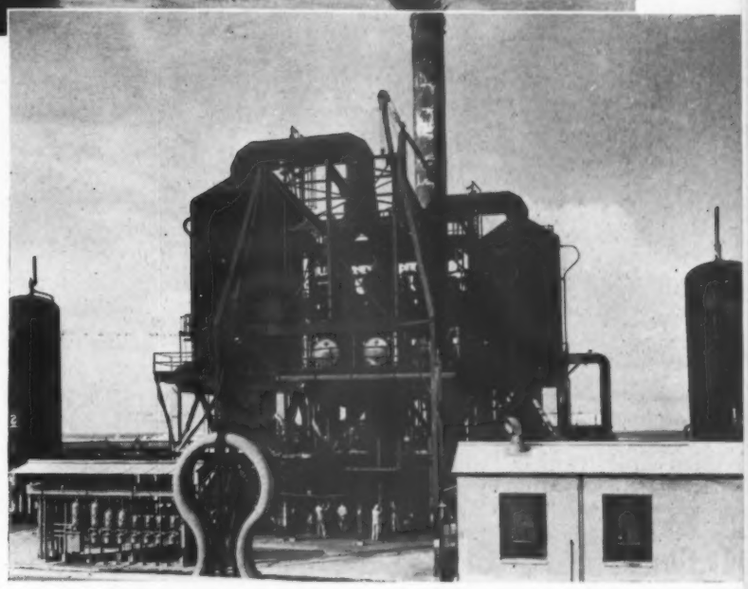
The 235-foot tall catalytic cracking unit first went on stream on December 5, 1943, less than twelve months after the start of the work of erection. In order to save transportation shipping space as well as the time that would have been consumed in a trial run, the unit was charged directly with synthetic catalyst for the initial run, although it has been the practice with other units to make preliminary runs on natural catalyst to determine the operability of the units. The initial run of the Aruba unit gave no unusual troubles and continued successfully at almost exactly 100 percent, of design capacity for 4,386 hours or just six months. This represented the longest initial run of any of the fluid catalyst cracking units up to that time.

The aviation gasoline expansion program has increased 100 octane aviation gasoline production from 3,500 to over 13,000 barrels per day. The catalytic cracking unit itself has been operating at design capacity and higher.



Above: Main Wings of Lago Hospital.

Left: Alkylation Plant.



Right: Pitch Stills.

Despite its small size Aruba is well among the first ten great world ports on a tonnage basis. In 1944 it averaged a monthly turnover of 422 ships; of these about 300 were shallow draft tankers which bring in crude oil from Lake Maracaibo, the rest being large ocean-going vessels. The lake tanker fleet, consisting of shallow draft ships with an oil capacity of 30,000 barrels, shuttles incessantly with its cargo of the refinery's principal crude oil between Lake Maracaibo, Venezuela and Aruba. The ships average about 12 trips a month, remaining in port only long enough to load or unload. The "Lakers", which sail under British, Panamanian and Venezuelan registry, have hauled 102 million barrels of crude oil within the last 12 months. In one month alone they have carried as much as 9,122,000 barrels of crude to Aruba; and on March 31, 1944 a record of 521,400 barrels was received at Aruba by lake tankers.

Water is Aruba's greatest supply problem, for fresh water wells are non-existant on the small coral island. All drinking water must be imported in specially fitted tankers from Bayonne, N. J., and an average of 240,000 gallons of imported water is used every day.

For washing and showering purposes brackish water (rain water which has found its way down to the water table in the coral formation) is pumped from wells in the company concession. The refinery boilers operate on distilled water produced from sea water in three evaporating plants. In addition more than 120,000,000 gallons of sea water are pumped to the refinery every day, chiefly for cooling purposes on the stills, and about an equal amount used for power generation.

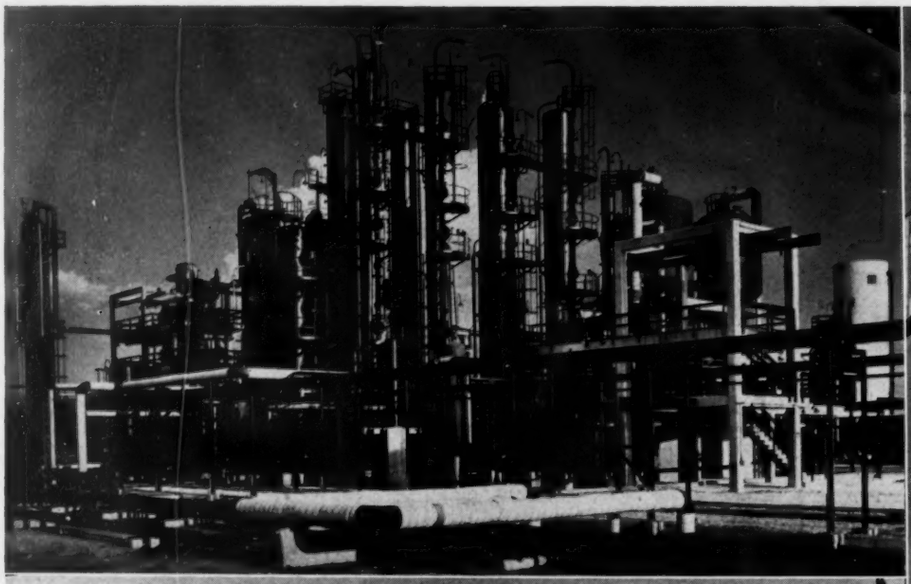
Of the 7,000 company employees about 6,400 are hired locally, and include nationals of some 56 countries. Fifty percent of the employees are Netherlands nationals, more than half of whom are Arubans. Less than eight per cent are United States nationals. Since 1939 the company has undertaken an apprentice training program for training fifty to sixty local boys from 14 to 18 years, recruited every year for important tasks in future operations.

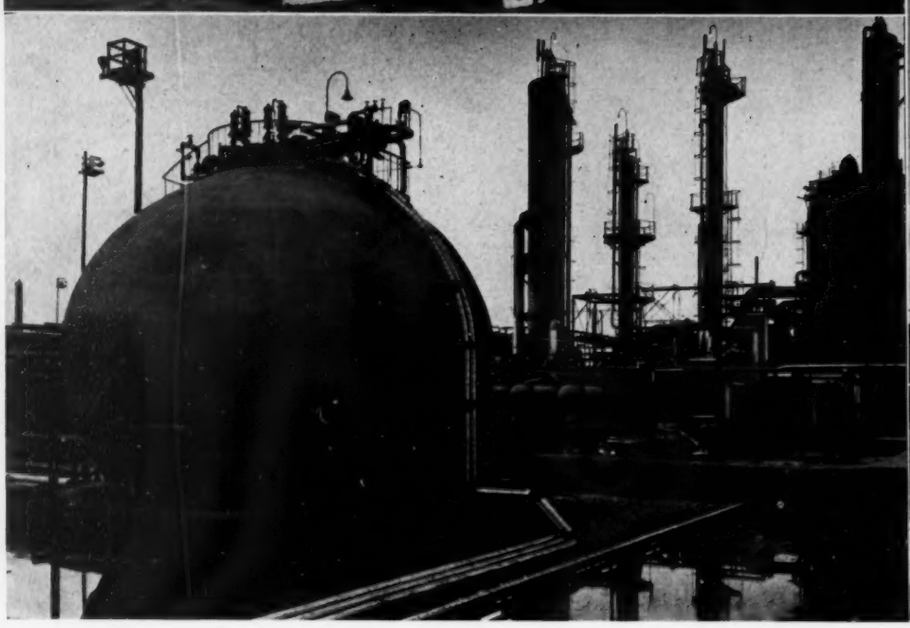
How much the apprentice training program means to Lago's future is a prime factor in the companys over-all policy. As a general rule, the company gives the first call on all jobs to resident Arubans, second call to the citizens of the Curacao area (the islands of Curacao and Bonaire), and third call to natives of the Caribbean area. The final call is given to outsiders, among whom are included North Americans.

Most of the United States nationals live in a company settlement provided with about 600 dwellings, three to six-room bungalows, bachelor quarters and girls' dormitories, a temporary Esso Club (the old one having burned in June 1942), a new church, a school, golf course, tennis courts, a skeet range and cleared beaches. To supply the commissary, mess hall and hospital with fresh sun-ripened vegetables the company is undertaking a hydroponics project. On an area of 5,400 square feet 40,000 pounds of tomatoes or their equivalent are expected to be grown each year. Four thousand tomato plants were set this year. These require, besides numerous chemicals, five hundred gallons per day of water. In spite of trouble of the same sort as beset ordinary soil gardening, it is hoped to have two hundred pounds of tomatoes a day in June and July. Beans and lettuce have also been planted.

One of the major welfare factors is a $200,000 community hospital. Begun in 1937 it was formally opened on February 22, 1939. More than 2,000 patients pass through its clinics every month and 200 are admitted to the hospital. An average of 75 patients are in the hospital every day. The pharmacy handles 1,200 prescriptions a month.

During the war several tankers plying between Lake Maracaibo and the island were sunk by enemy submarines. Many tankers loaded at Aruba were sunk by enemy submarines while enroute to the United States or Great Britain. Early in the morning of February 16, 1942 an enemy submarine shelled the refinery and torpedoed two lake tankers lying off the reefs outside the harbor, setting them afire. One sank where torpedoed and the other was salvaged and repaired and is back in service. The refinery was not damaged, but the attack forced the refinery to black out. Thereafter all operations had to be carried out under complete blackout conditions and shift workers at night guided themselves through the plant by flashlights taped down to pin-point size. Refinery operations and new construction were greatly inconvenienced. But the inconvenience failed in any way to reduce the refinery's output of vital petroleum products for the planes, trucks, tanks, submarines, warships and cargo ships of the Allied forces.





Robert Yarnall Richie Pho

Top: Treating Plant at Tutwiler Refinery.

Above: Butadiene Plant—Pressure Storage (foreground) and Purification Unit (right.)

Right: Alkylation Unit A.

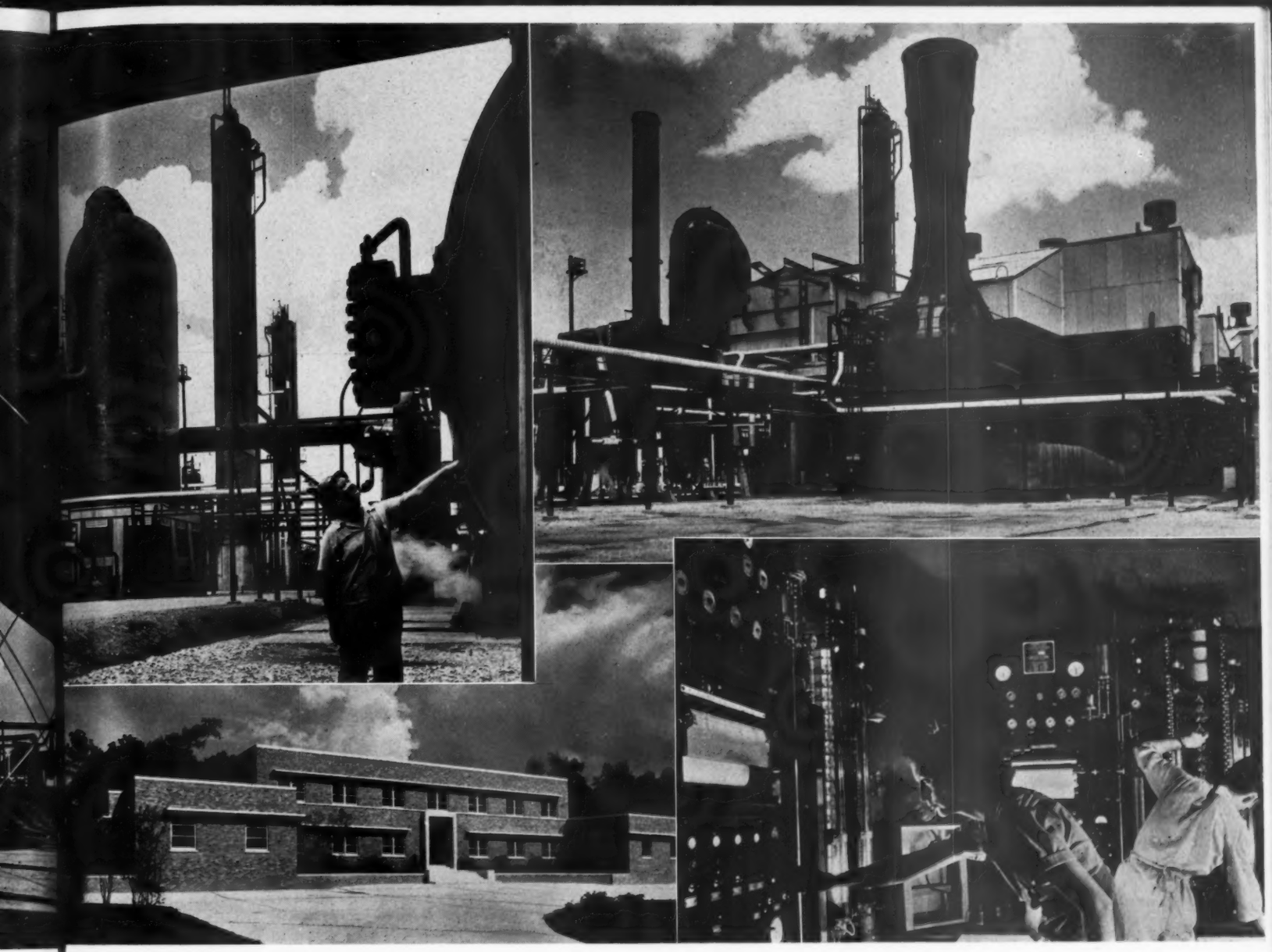
TUTWILER REFINERY OF CITIES SERVICE HAS MADE GOOD IN FIRST YEAR'S OPERATION

Great Plant at Lake Charles, Louisiana, Built From Scratch Primarily to Provide Products for War Use Has Exceeded Expectations and Among Other Products Has Supplied Aviation Fuel to Keep a Thousand Planes Over Germany Each Day

AMONG the many refinery plants built in the United States in execution of war program the great Tutwiler refinery of Cities Service Refining Corporation at Lake Charles, Louisiana, is unusual in several respects. Though a fully integrated refinery it was built primarily to provide materials of war, principally high octane aviation gasoline and butadiene, and was designed for maximum output of these products. Unlike many other war installations it was not constructed around the nucleus of an existing refinery but was built from scratch on a site of 600 acres that first had to be cleared of a pine forest. In its design the company's engineers and those of the M. W. Kellogg Company, its constructors, were able to embody the most advanced features developed by previous experience without the necessity of tieing in new units with others previously in operation. Since its formal dedication, in May 1944, the refinery has been in operation something more than a year. This period of operation has now provided a basis for a preliminary inspection of the results achieved by this huge war plant, in comparison with the expectations of the engineers who planned and organized it. Getting the record down to simplest terms, this is what has happened.

(1) The output of war-needed products has fulfilled the promises of blueprint estimates. In some instances, specific items have been produced in considerable excess of rated plant capacity.

(2) Though bolstered by a minimum of standby equipment, which was limited so as not to divert vital materials from other war projects, the plant exceeded normal operating expectations. The first of the three fluid catalyst cracking units was not taken off-stream until after a non-stop record of 300 days — and then it was



Top Left: Stripper Scrubber Tower, Butadiene Plant.

Top Right: Dehydrogenation Unit, Butadiene Plant, Boiler House in Foreground.

Bottom Left: Administration Building, Tutwiler Refinery

Bottom Right: Laboratory Gas Analysis Room.

done as a measure of precaution, to avoid the possibility of having two units off-stream at the same time.

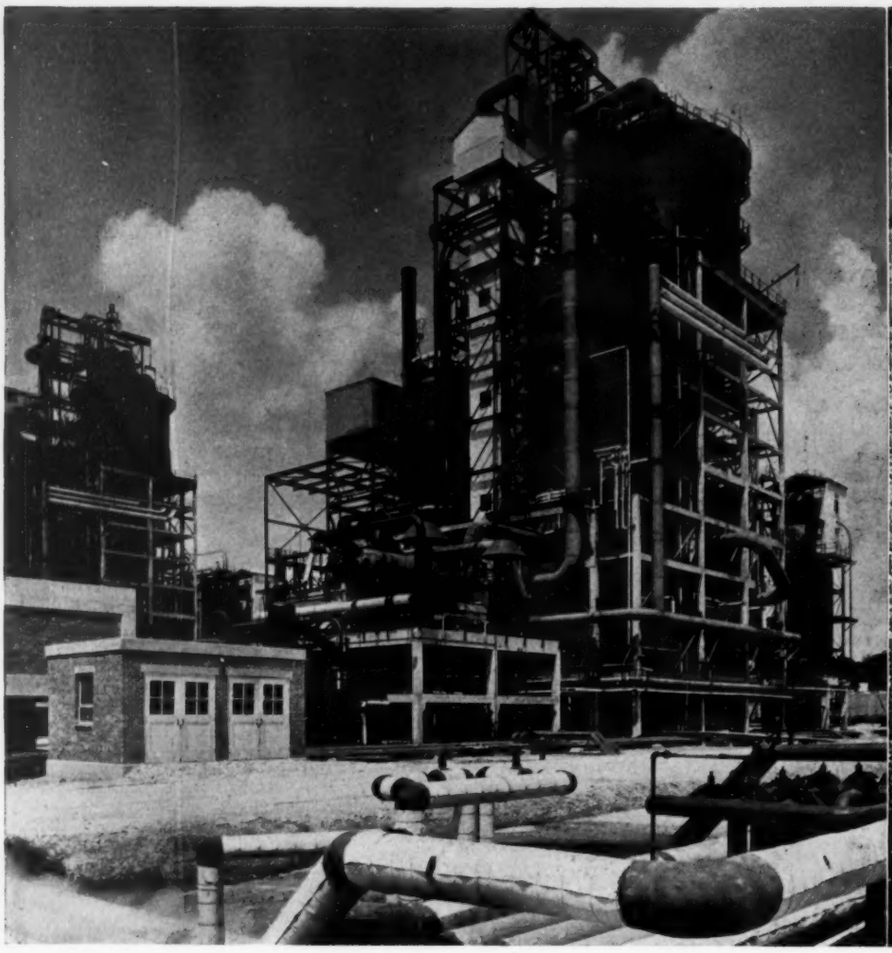
(3) Despite the speed with which the plant was brought into being, the necessity of eliminating as much critical material as possible, and the disadvantages of developing operating crews from scratch, there have been no abnormal maintenance problems. It is true, as it is of every new plant, that some unanticipated troubles have been encountered but these troubles were met as they arose, and they were offset by delivery beyond what had been estimated.

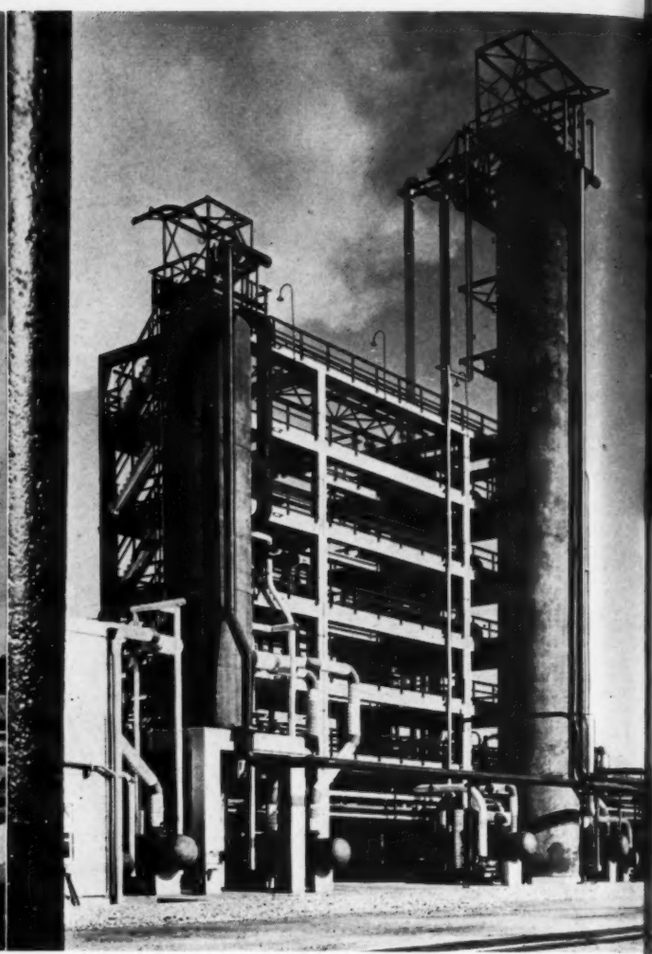
A statement that operation of the Lake Charles plant has, during the past year, gone pretty much "according to plan" is a perfectly true summation, but at the same time it has the weaknesses of over-simplification. To obtain this over-all planned accomplishment it was necessary to make many an emergency adjustment, to develop some new techniques, and at times to take some calculated risk that these measures might fail to meet the need. Bearing these things in mind, it is easy to understand the pride of achievement — in end results — which the technicians at Lake Charles have in looking back at the manner in which over-all performance was maintained despite all difficulties.

It is an achievement shared by many units and many men. The superb performance of the three catalyst units has a dramatic quality and they are, of course, the heart of the refinery. This is, however, an integrated plant whose operation ranges through 114 buildings. The two topping units, for example, breaking the crude into gasoline fraction overheads, naphtha, gas, oils and residual oils, are as imposing in performance as in towering structure. The alkylation and isomerization facilities, working in closer relation to one another than is the case in most refineries, were designed for a daily output of 9,500 barrels, and they met every expectation.

The deasphalting unit has been one of special interest to refinery men because, so far as is known, the Lake Charles plant is the only one in the world which utilizes propane deasphalting to produce a charging stock for the catalytic crackers. This involved a number of technical developments, the practical value of which has now been demonstrated, and these may become of major importance in the post-war era.

In any modern refinery aiming at maximum results, the treating plant must be capable of top efficiency. The Lake Charles plant consists of five separate units. These remove alien substances and thus develop a product as pure as technical science can provide. To cite just one item, it requires a series of acid-treated caustic washings, of water washings, of rock-salt drying and other treatments to produce a furnace oil which will be bright and clear for market.





Left: Catalytic Cracking Unit. *Right: Alkylation Unit.*

These are but a few of the many vital processes which, monitored by constant laboratory study, have shared in credit for the first-year period. They are supported by numerous auxiliary operations, some of them huge in themselves. The power plant, for instance, is big enough to serve a city such as Omaha, and it had to be planned to avoid any possibility that there would be a failure. There hasn't been, and there is no fear that there will be.

The accomplishment in maintaining the vital and sensitive array of instruments and automatic controls deserves mention at this point. Entirely aside from thermometers, gauge glasses and pressure gauges, there are 1,250 of these instruments installed in the basic refinery. In the initial layout of the instrument assembly every effort was made to anticipate the extreme demands of war plant operation. Bulb type temperature controllers were eliminated because of the proneness of this type to breakage of capillary tubing and over-ranging of the instrument, and the long time required for repairs. Standardization was emphasized to diminish the need for spare parts and to assure flexibility.

The effects of this planning have made themselves evident during the first year of operation. Troublesome instruments have generally been adjusted without taking them out of service with the result that their units have continued to play their part in keeping the plant in capacity production.

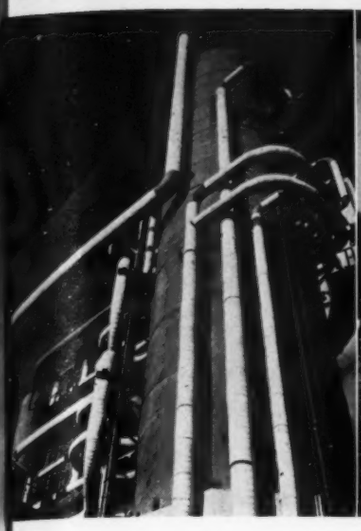
A tour of the refinery and talks with maintenance men would, of course, point up some difficulties, such as in the acid plant where a number of leaks presented the need for speedy repairs. However, this type of plant is normally subject to this special problem and again the extent of achievement is the best gauge for measuring the operation. During its part-year run of 1944, the acid recovery unit produced more than 77,000 tons of sulfuric acid. Designed for a 350-ton daily output, it was delivering at 128.5 percent of rated capacity in December, providing a supply in excess of all requirements at Lake Charles, an excess made available to other aviation gasoline refineries.

Though based on the soundest of engineering calculations, the construction of such a giant as the Tutwiler refinery necessarily involved experimental features. For this reason its experience is being studied with a view to post-war applications. For this reason also, entirely apart from the patriotic motives which provided the first cause for cooperation, the undertaking has had the sympathetic and invaluable assistance of other oil companies and of refinery experts generally.

Thus, when the record 300-day run of Unit A was completed on February 5, it was natural that those gathered as observers should include the staff members of other operators of fluid units and of others of similar technical interest. It was, incidently, the advice of these fluid unit operators which developed the method of flushing the fractionating tower to relieve the threat of plugging because of coke accumulations in the tower bottoms.

Cities Service officials had announced that three weeks had been assigned for the turn-around of Unit A and that 20,000 man-hours would be employed in carrying out an improvement program. As the findings of the inspection had been largely foreseen, adequate supplies were already on hand to carry out repairs and improvements, with the result that the maximum benefit of this manpower could be obtained. Among the planned undertakings were the modification of the fractionator, the strengthening of the precipitators, which had shown some structural weakness inviting to leaks; the installation of some additional instruments, and of some other auxiliary equipment.

While it is natural, in studying accomplishments, such as these, to emphasize the performance of physical equipment, the year-proven success of the Lake Charles plant is peculiarly an achievement also of personal skills, of ingenuity and of specialized job-understanding. The plant itself was, of course, the ultimate in engineering, requiring the highest type of technical knowledge. Beyond that, however, lay the problem of getting men who could be de-



Fractionating Column.

Laboratory Knock Engine Test Unit.

Right: George L. Mateer, General Superintendent and W. W. Lowe, Vice President and General Manager.

pended upon to keep this vital war project in peak production.

Mass manufacturers, engaged in assembly operations, have dramatized the importance of every employee to the continuity of the assembling line, even though his task is merely the turning of a nut on an obscure bolt. If the operation of a refinery were simply an assembly process such as this, the personnel problem would be reduced to the basic one of assigning one man here, another there, until the line was filled. Instead, the resemblance to assembly methods ends pretty much in the interlocking of operations into a continual flow of production.

Cities Service fortunately had a nucleus of technical men who could be supplied to Lake Charles from the staffs of affiliated companies, although usually this could be done only through the willingness of other men to take on an increase in their own work-loads. A few more were obtainable, from outside sources. In general, however, these men were faced with specialized assignments for which they had a broad technical preparation but for which they were unprepared otherwise. They needed specialized training and, due to pressure of time, it had to be obtained intensively.

Long experience has shown the Navy that no matter how standardized the design of a ship, little differences are bound to emerge which give character to a vessel and distinguish its operation from the apparently identical ship built on the adjoining way. For this reason, it has been found to be a second procedure to have those who will be charged with the command right on the job when the ship is being built, to learn every phase of its construction. The same is true of a refinery.

Cities Service did just that with the men to whom it was going to entrust responsibilities in the operation of the Lake Charles plant. Many of them went directly to points where the equipment was being built, and they took intensive courses in how this equipment was being constructed, why it was being built that way, what is was expected to do, and what probably would be wrong if at any time it failed to deliver according to specifications. Some key men went to other refineries to study their processes. Thus, when the Lakes Charles plant arose on the 550 acres cleared for it out of the 2500 acres of tree-laden land which Cities Service had purchased, trained personnel was ready.

The full story of the accomplishments of these men and the huge plant they direct cannot, of course, be revealed until the war has no more secrets. It is known, however, that the gasoline produced at Lake Charles helped mightily to speed up victory in Europe. This output of gasoline, supplemented by other vitally needed war supplies which are sourced in Lake Charles, will now be used against Japan, which General Marshall says we shall blast daily with bombs from 1,000 superfortresses.

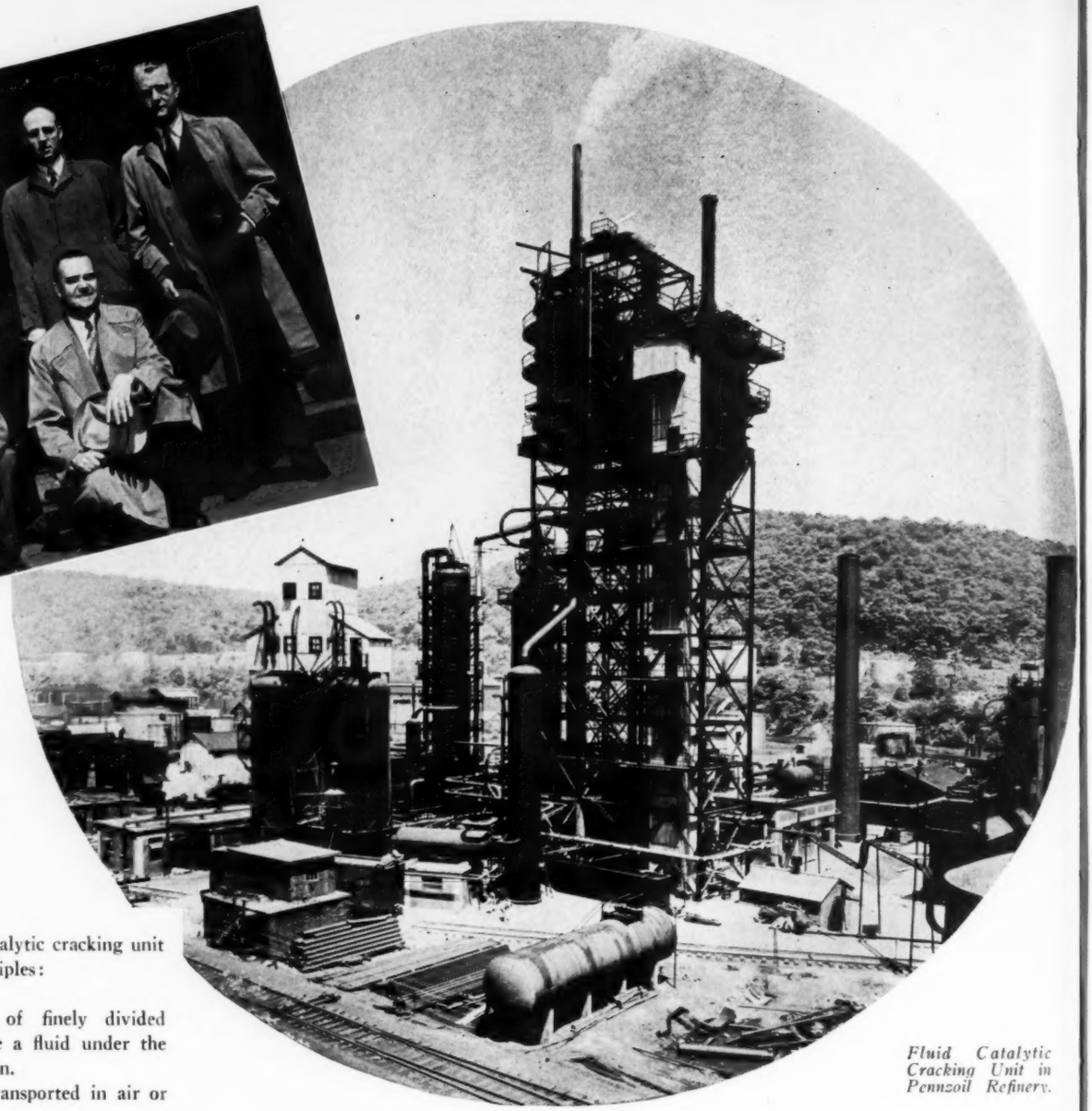
There are varying ways of viewing the Lake Charles refinery. Some like statistics and they are fantastically available, from the 16,000,000 bbls. of all products produced in little more than a half of 1944, down to little picture items such as "It uses more than 43,000,000 gallons of water a day, enough to supply all the homes of Chicago." Cities Service officials have become quite used to these figures and see no point in reiterating them. Asked if the year of operation has satisfied them as to results, they say it has, if only because it has met the objective fixed by W. Alton Jones, president of the company, at the Lake Charles dedication ceremony.

"We dedicate this activity," Mr. Jones said, "to our boys on the battlefronts in the hope that the added material of war produced here may bring them home sooner and bring more of them home! If the output of this plant helps to shorten the war by one day or to save the life of one American boy, the 25,000,000 man-hours put into its construction and the millions more that will go into its operation, will not be in vain."

North Topping Unit, Blow Down Drum in Foreground.

Watching the various operations of this masterfully integrated project, stubbornly meeting the war-pressed demands for night-and-day production, with men matching equipment in the record of performance, officials of the Lake Charles Tutwiler refinery are confident that this dedication has been superbly met throughout the first year. With the experience now obtained, they are confident also that an equally good, and probably better, job will be done from this point on.

Representatives of Four Refining Companies that Joined Together in the 100-Octane Gasoline Project. Top Row—Left to Right: W. S. Zehrung, Pennzoil; W. R. Reitz, Quaker State; A. W. Scott, Wolf's Head; A. B. Weingard, Continental. Bottom Row—J. C. Grosser and D. W. Grant, Pennzoil.



Fluid Catalytic Cracking Unit in Pennzoil Refinery.

PENNZOIL COOPERATIVE 100-OCTANE GASOLINE REFINERY

By Paul Truesdell and W. E. Lemen

Universal Oil Products Company

THE operation of a fluid catalytic cracking unit is based on three main principles:

(1) A catalyst consisting of finely divided solids will behave much like a fluid under the proper conditions of aeration.
(2) The catalyst may be transported in air or vapor streams.
(3) The catalyst will settle out into a dense phase when a stream of air or vapors carrying catalyst is introduced into a chamber of considerably larger diameter than the transporting line.

The fluid catalytic cracking unit of Pennzoil Refinery, Oil City, Pa., employs these three principles to carry out two main operations continuously and simultaneously:
(1) Cracking oil in the presence of catalyst.
(2) Maintenance of catalyst activity by burning off the coke deposited on the catalyst during the cracking reaction.

In order to minimize coke formation, and for other reasons, catalytic cracking is carried out at low pressure. The normal operating pressure in the reactor is about 10 pounds. The reactor is a 13 ft. by 54 ft. vessel mounted vertically near the ground. The course of the process can readily be followed on the accompanying flow diagram of the catalytic cracking unit.

The regenerator, operating at one pound pressure, is a 20 ft. by 32.5 ft. vessel elevated about 150 ft. The static head developed by a column of fluidized catalyst in a vertical pipe off the bottom of the regenerator, known as the regenerated catalyst standpipe, is sufficient to feed catalyst into the reactor. The regenerated catalyst standpipe has an inside diameter of 18 inches. Fresh oil feed passes through a G-fin heat exchanger in which its temperature is raised to 300°F. by exchange with a portion of the slurry-circulating stream from the bottom of the fractionator, and thence to the heater in which the temperature is raised to 750°F.

The partially vaporized charge enters the catalyst section at the line through which catalyst at a temperature of 1050-1100°F. is circulated to the reactor. This line is the injector. About 1300 pounds per hour of steam is introduced at the injector, to assist the mixing of catalyst and oil. The catalyst from the regenerator supplies the greater part of the heat required for vaporizing and cracking the charging stock. Current operation is carried out with a reactor temperature of 950°F.

This article is based on a release from the U. O. P. Co. under the title "Four Refineries Join to Convert Common Cracking Plant to War". It is of interest because it contains a detailed description of the arrangements and operation of a relatively small-scale refinery embracing catalytic cracking, gas concentration and alkylation.—Editor.

The reactor temperature is largely a function of the regenerator temperature, the catalyst circulation rate, and the preheat on the oil feed to the reactor. A constant temperature is maintained in the reactor by minor adjustments of the catalyst circulation rate and preheat on the fresh feed, while the regenerator temperature is allowed to vary within a 50°F. range.

With a regenerator temperature of approximately 1100°F., the catalyst circulation rate is about seven tons per minute, which maintains a ratio of 15 pounds of catalyst per pound of oil.

The combined catalyst and oil vapors enter the reactor through a perforated distribution grid located near the bottom of the reactor, and of such size that an annular space is left between the edge of the grid and the walls of the reactor. The catalyst separates into a dense phase above this grid. The vapors passing upward through this dense phase keep it agitated so completely that the bed is at a substantially uniform density.

The oil-catalyst contact time depends upon the weight of catalyst in the reactor rather than the volume, since the density of the catalyst in the dense phase may vary with other operating conditions. A constant weight of catalyst is maintained in the reactor by a controller actuating the slide valve at the bottom of the regenerated catalyst standpipe to maintain a constant differential across pressure taps at the top and bottom of the reactor. Thus a constant weight of catalyst is maintained by balancing the catalyst flow into the reactor against that withdrawn.

Most of the catalyst entering the reactor is withdrawn from the dense phase through the annular space around the inlet grid, passing downward into a conical section and thence into the drawoff line or reactor standpipe. Steam is injected at three levels around the conical section in order to strip hydrocarbon vapors from the spent catalyst. About 3000 pounds per hour of steam is used.

Hydrocarbon vapors, steam and some entrained catalyst pass upward through a disengaging space into a multiclone separator mounted in the top of the reactor. The multiclone is a series of small cyclone dust separators arranged to operate in parallel.

Catalyst knocked out by centrifugal action in the multiclone is returned to the dense phase through a collection hopper and dip leg. Hydrocarbon vapors carrying only a small amount of catalyst pass overhead from the multiclone to the fractionator, entering at a point just above the liquid level of the bottom.

The fractionator is an 11 ft. by 65 ft. tower containing 12 trays above a center wall, and two trays, two perforated plates, and seven perforated disc and donut pans below. Heat is recovered from the lower section by circulation of fractionator bottoms through a steam generating heat exchanger which produces 7000 pounds per hour at 125 pounds pressure.

Oil leaving the steam generator at 400°F. is returned to the fractionator at the upper perforated tray, along with the bottoms stream from the fresh feed exchanger. This circulation of bottoms not only supplies the necessary cooling, but also provides the liquid wash for scrubbing entrained catalyst from the rising vapors. The concentration of catalyst in the bottoms or slurry is maintained between 0.5 and 1.0 pound per gallon by continuously returning column bottoms to the reactor via the injector.

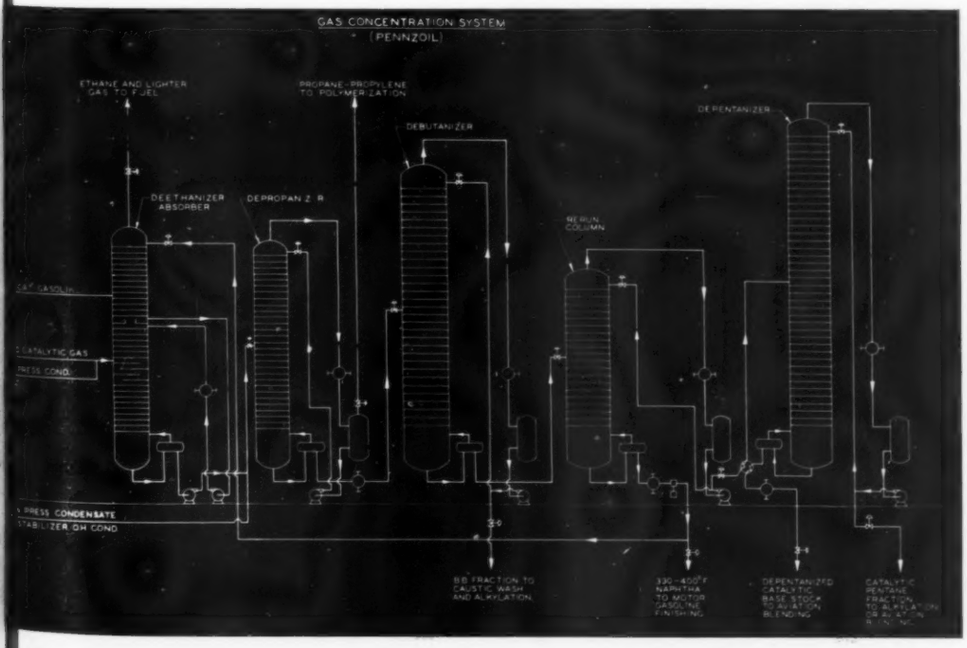
Mid-column cooling is provided by circulating a sidecut drawn from the center wall into an accumulator through a low pressure steam generating heat exchanger which produces about 3000 pounds of 40 pound steam per hour. This stream leaves the exchanger at 300°F. and is returned to the column three trays above the center well. The sidecut or cycle stock is pumped directly to the thermal cracking unit.

The fractionator operates at a pressure of five pounds. The bottom temperature is held at 550-570°F. and the top temperature is maintained at 225°F. by returning gasoline from a reflux accumulator to the top of the column. Water from the condensation of the steam injected into the reactor is withdrawn continuously from a leg on the reflux accumulator. Overflow from the accumulator passes through a subcooler into a receiver from which the 400°F. e.p. unstabilized gasoline is pumped to the gas concentration unit, while the gas goes to the compressor suction drum and thence to the first stage of a 600 h.p. 2-stage gas-engine driven Cooper-Bessemer compressor. Discharge from the first stage at 50 pounds pressure passes through a cooler into a receiver. Low pressure condensate is pumped to the gas concentration depropanizer. Fifty-pound gas passes to the second stage of the compressor in which the pressure is raised to 225 pounds. The second stage discharge passes through a cooler into a high pressure receiver from which the gas and high pressure condensate go to the gas concentration deethanizer.

Spent catalyst leaves the bottom of the reactor at 900-950°F., passes through a slide control valve and drops into the line through which air for regeneration is introduced. The catalyst is picked up by this air stream and carried upward into the regenerator through the regenerator riser, inside diameter of which is 36 inches. The rate of catalyst circulation is determined from the pressure differential between two points on the riser, and the circulation rate is adjusted by resetting the controller which actuates the spent catalyst slide valve to maintain a constant differential on the riser.

The combined air and catalyst stream passes through a perforated grid into the main section of the regenerator in which the catalyst settles into a dense phase. The temperature in the regenerator is 1050-1100°F. This temperature is maintained by burning coke deposited on the catalyst during cracking. Coke on the spent catalyst amounts to 1.0 to 1.5 percent by weight. This is reduced to 0.5 to 1.0 percent in the regenerator. The total quantity of coke burned in the regenerator is 30-35 tons per day. Regeneration air is supplied by a turbo-blower unit capable of delivering 11,600 standard cubic feet at a discharge pressure of 18 pounds. The air rate is controlled by adjusting a butterfly valve in the blower discharge to maintain an oxygen concentration of 2-3 percent in the combustion gases leaving the regenerator.

Combustion gases and some entrained catalyst separate from the dense phase and pass upward through a multiclone separator mounted in the top of the regenerator. Catalyst separated by centrifugal action in the multiclone drops into a hopper from which it is returned to the dense phase through a dip leg. Regenerated catalyst is withdrawn from a hopper in the dense phase passing downward through the standpipe into the reactor to complete the catalyst circuit.



Combustion gases from the regenerator pass overhead at 1000-1050°F., through a waste heat boiler in which sufficient heat is recovered to generate 3000 pounds of 40-pound steam per hour. The partially cooled gases are further cooled to 375-400°F. by the injection of water into the duct below the waste heat boiler. From this duct the gases pass into a Cottrell electrical precipitator in which the catalyst particles are charged and collected on the plates of plate and frame electrodes across which a high voltage electrical discharge passes. The catalyst recovered from the plates drops into a hopper and passes downward in a small standpipe, through a slide control valve and into an air stream which carries it back to the regenerator. Combustion gases carrying a small quantity of catalyst fines are released at the top of the precipitator.

The total inventory of catalyst in the unit is approximately 125 tons, of which 35 tons is above the grid in the reactor and 55 tons above the regenerator grid. The catalyst replacement on this unit amounts to approximately one ton per day.

In order to minimize the use of alloy steel the vessels and lines in service over 1000°F. are internally insulated with four inches of soft insulating block and three inches of Bigelow-Liptak refractory tile.

The catalyst used presently is a synthetic silica-alumina having an average particle size of about 22 mesh.

Gas Concentration Unit

The function of this unit is to classify and separate the various hydrocarbon fractions contained in the catalytic gasoline, the compressor condensates, the stabilizer overhead condensate, and the high pressure gases, and distribute them to the best advantage. This involves a number of specific jobs, namely:

(1) To recover C_3 and heavier hydrocarbons from the cracking plant gases.
(2) To segregate the C_3 fraction for feed to the alkylation or polymerization unit.
(3) To segregate the C_4 fraction for alkylation feed.
(4) To rerun the 400°F. e.p. catalytically cracked gasoline to 330-340°F. base stock.
(5) To segregate the C_5 fraction for aviation gasoline blending or charging to the alkylation unit.

Catalytically cracked gasoline of 400°F. e.p., high pressure catalytic and thermal gas, and high pressure compressor condensate are charged to the deethanizer. (See flow diagram of this unit.) This is a 4 ft. by 60 ft. column containing 28 trays and operating as a combination absorber and stripper. Catalytic naphtha is circulated over the top at the rate of 15-20 gallons per minute, as the absorption medium, and cooling is supplied at the center of the column by circulation of liquid from a reservoir between the 13th and 14th trays, through an intercooler and back into the next tray below at the approximate rate of 50-75 gallons per minute. The bottom temperature is maintained at 200°F. by an external steam heated reboiler; top temperature is 100° F. The column is operated at 200 pounds pressure. Ethane and lighter gases are removed overhead and go directly to the fuel gas system. The bottoms, consisting of C_3 and heavier hydrocarbons boiling up to 400°F., are charged to the depropanizer which also receives a low pressure condensate from the catalytic cracker and stabilizer overhead-condensate from the thermal cracker.

The depropanizer is a 6½ ft. by 53 ft. column containing 30 trays and operating at 250 pounds pressure. Top temperature is maintained at 110° F. by refluxing with part of the overhead condensate at the ratio of 4-5:1, and the bottom temperature is held at 280°F., with heat supplied by an external steam heated reboiler.

The propane-propylene overhead fraction may be charged to the polymerization unit, the alkylation unit, or released as a gas to the fuel system. Bottoms consisting of C_4 and heavier fractions boiling up to 400°F., flow to the debutanizer under system pressure.

The debutanizer is a 6-ft. by 69-ft. tower with 28 trays operating at 50-100 pounds pressure. Top temperature is maintained at 130-145°F., by refluxing a part of the overhead condensate at the ratio of 1-2:1; bottom temperature is maintained at 325°F., by an external steam heated reboiler, using 275-pound steam.

The BB fraction recovered overhead, consisting of isobutane, normal butane, and butylenes, is caustic washed. This fraction is the normal feed to the alkylation unit. The bottoms from this tower, consisting of C_5 and heavier hydrocarbons boiling up to 400°F., flow under system pressure to the rerun column. The rerun column is 6½ ft. by 38 ft. with 20 trays, operating at five pounds pressure. Top temperature is maintained at 225°F. by refluxing part of the overhead condensate at a ratio of 1-2:1, and bottom temperature is held at 370°F. by means of an external steam heated reboiler. The overhead is 330-340°F. e.p. debutanized base stock which contains all of the catalytic C_5 fraction.

The bottom stream is 300-400°F. catalytic naphtha, part of which is pumped over the top of the deethanizer as absorber oil while the remainder goes to storage, later to be blended with the thermally cracked and reformed gasoline. The overhead from the rerun column, after passing through a caustic scrubber, enters the depentanizer.

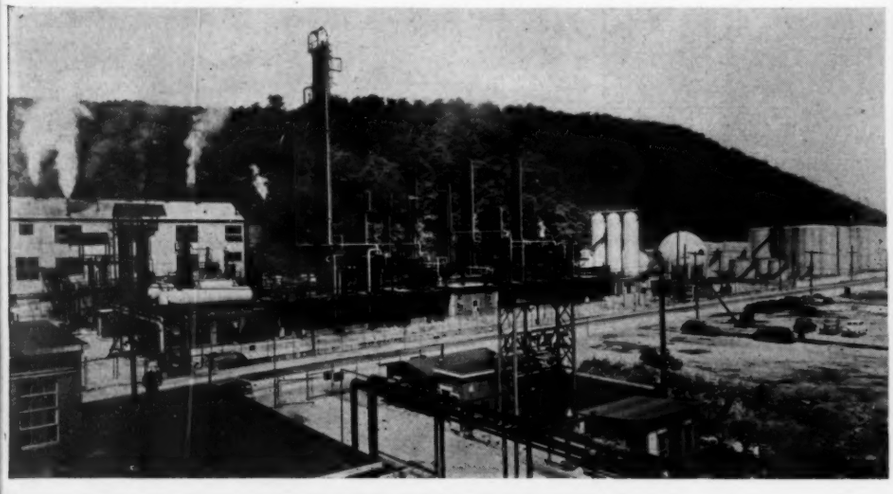
The depentanizer is a column 5 ft. by 76 ft. with 40 trays, operating at 25 pounds pressure. Top temperature is maintained at 140°F. by refluxing part of the overhead condensate at a ratio of 2-3:1. Bottom temperature is held at 250°F. by an external steam heated reboiler.

The overhead is C_5 fraction which goes to storage. The bottom stream is depentanized catalytic base stock which represents about a 20 percent yield on the gas oil-kerosene charge to the cat cracker. The caustic treated base stock is inhibited with U.O.P. inhibitor, either No. 4 or No. 5, blended with alkylate and isopentane, ethylized to make 100 octane gasoline.

HF Alkylation Unit

The process employed in this unit combines isoparaffins with olefins in the presence of a catalyst

Pennzoil Plant No. 3, Including Boiler Plant (Left Background) Alkylation Unit, Gas Concentration Unit and Pressure and Atmospheric Storage.



With J. C. Grosser, These Men are Responsible for the Operation of Plants 2 and 3. Top Row—Left to Right: L. R. Brandon; Jack Stevens; W. E. Lemen; Bruce Rooker; Jack Beighley; Kenneth Smith. Bottom Row: Ralph Crowther; Alan Hoffman; Clayton Fontaine; Harry Fennick; Raymond Dardes and Bob Swoope.

to produce alkylate, an essential component of 100-octane aviation gasoline. Isobutane is the isoparaffin employed; butylenes are the olefins used in greatest volume, although propylene and amylenes are also employed. While the fluid catalytic cracking process is the major producer of the components of 100-octane gasoline, the alkylation process is really the key to 100-octane gasoline yield, because the quantity of alkylate available usually governs the quantity of aviation gasoline that can be made.

Alkylation Feed — Olefins

Propylene	2.8%
Butylenes	73.4%
Amylenes	23.8%

The catalyst used in the process is anhydrous hydrogen fluoride which is a liquid under a few pounds pressure. The process is divided into four main sections: Feed preparation, contacting, fractionation, and acid regeneration.

The olefin-containing feed recovered in the gas concentration unit is charged from intermediate storage through the feed dryers which are three 2-ft. by 14-ft. towers filled with Florite, a commercial desiccant, manifolded to permit the use of two towers while the third is being regenerated. The feed flows directly from the dryers to two No. 30 Stratco contactors, manufactured by Stratford Engineering Company. Volumetric capacity of the contactor is 3100 gallons. Internal circulation is provided by means of an impeller at the bottom of the contactor. The impeller is rotated at 825 r.p.m. by a 150-horsepower Westinghouse steam turbine operating at 3500 r.p.m. through a reduction gear. The contactors are manifolded for parallel flow of the olefin-containing feed, and for series flow of the isobutane recycle and acid, the effluent from No. 1 contactor passing to No. 2. In recent operations it has been found advantageous to dry all or a part of the isobutane recycle by passing it through the dryers along with the BB feed. Thus a part of the isobutane recycle also passes to the contactors in parallel.

The alkylation unit was designed for 6:1 ratio of isobutane to olefin, based on the total feed to the contactor (fresh feed plus isobutane recycle) and the space time was 30 minutes. The throughput has been increased to the point where the yield of alkylate is nearly twice the design production.

The high throughput has reduced the isobutane: olefin ratio to as low as 3-4:1 and the space time to 15-20 minutes, and has resulted in only slight sacrifice in quality of the alkylate.

Intimate mixing of acid and hydrocarbon takes place in the contactors which operate at a pressure of 85 to 125 pounds. Since heat is generated in the reaction, the contactor is provided with a tube bundle through which water circulates. The tubes are Griscom-Russell G-fin; the fin has an outside diameter of 3.37 inches. The tubes are seamless steel, 1½ inch in diameter. Temperature in the contactors is maintained at 75-100°F. Space time is 15 to 30 minutes.

From the contactors, the acid-hydrocarbon mixture goes into the acid settler, a horizontal 8-ft. by 30-ft. vessel provided with baffles, where it separates into acid and hydrocarbon phases. The hydrocarbon phase is drawn from the top of the settler into the depropanizer charge drum, a 3-ft. by 30-ft. vessel. Feed to the depropanizer is pumped from this drum through a preheater in which its temperature is raised to about 180°F.

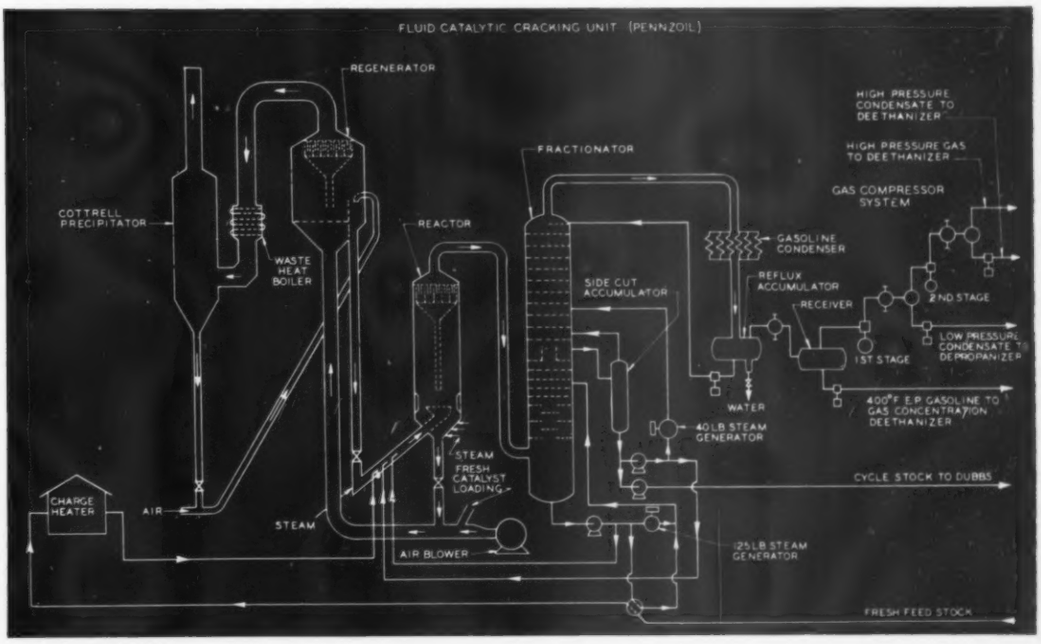
The depropanizer, a 5-ft. by 40-ft. tower with 35 trays, operates at 300 pounds pressure. Top temperature of 125°F. is maintained by refluxing a portion of the overhead condensate at a ratio of 20-30:1, and bottom temperature is held at 240°F. by means of an external steam-heated reboiler. Because the propane overhead stream contains some free acid, it is pumped to a stripper for separation of propane and acid.

Hydrogen fluoride dissolved in hydrocarbons has an abnormally high volatility; this fact is made use of in the HF stripper which is a 1½-ft by 27-ft fractionating column packed with 20 feet of ½ inch carbon Raschig rings. The charge is fed near the top. An internal steam coil at the bottom supplies the heat necessary for stripping; i.e., 125°F. at the top and 140°F. at the bottom.

A portion of the propane feed, together with all of the free HF, passes overhead into the depropanizer vapor line. The remainder of the propane passes from the bottom of the stripper through a small drum filled with limestone and thence to the fuel gas system. Acid recovered in this system collects in a leg on the depropanizer receiver from which it is returned to the settler. One of the primary advantages of the HF alkylation process is the ease with which the concentration of acid in the system is maintained by continuously withdrawing less than two percent of the circulating acid for regeneration. This procedure keeps the acidity at the desirable 90-95 percent operating strength; thus avoiding the problems involved in reconcentrating or disposing of large quantities of spent acid.

Regeneration involves two steps; first, the removal of any polymer or tar formed in the reaction; second, the removal of water. The first step is accomplished in the regenerator, which is a 3-ft. by 30-ft. tower with six side-by-side pans below the feed line and one foot of carbon Raschig rings. The tower operates at 90 pounds pressure and at a temperature of 242°F. The HF is flashed overhead by introducing stripping isobutane through a superheater operated at 360°F. Polymer or tar is withdrawn from the bottom of the column and sent to the boiler fire-boxes. The greater part of the acid overhead is returned to the settler along with the stripping isobutane. A small portion of the acid overhead is charged to the dehydration column, in which the water is removed from the bottom as a constant boiling mixture containing about 40 percent acid, which is disposed of by neutralization with lime and precipitation of the calcium fluoride. The acid overhead is returned to the settler along with the overhead from the regeneration column.

The dehydration column is 25 ft. high. The lower 10 ft. is steam jacketed and has an inside diameter of 18 inches. The upper part is 14 ft. high, with a 14 in. diameter, and is filled with ½ inch carbon Raschig rings. This column is operated at a 100 pounds pressure, with a top temperature of 175°F. and a bottom temperature of 300°F.



The hydrocarbon stream leaving the bottom of the depropanizer contains a small amount of combined fluorides which is removed by passing this stream through bauxite at 200-240°F. and 290-300 pounds pressure. The bauxite is contained in two towers, each 4½ ft. by 25 ft. The towers are manifolded for flow through one tower, while the other is being dumped and refilled. The hydrocarbon stream from the bauxite tower flows to the deisobutanizer, a 7-ft. by 110-ft. tower, containing 50 trays and operating at 100 pounds pressure. Overhead vapors from this column are partially condensed and passed into an accumulator from which reflux is returned to the top of the column at a ratio of 2-2.5:1, to maintain a temperature of 120°F. The net overhead passes through a secondary condenser into the final receiver from which the isobutane recycle is returned to the contactors. A bottom temperature of 250°F. is maintained by an external steam-heated reboiler.

Bottoms from the deisobutanizer are charged to the debutanizer which is a 3-ft. by 47-ft. column with 25 trays operating at 80 pounds pressure. Overhead from this column is partially condensed and passed into an accumulator from which reflux is returned at a ratio of 3.5-4:1 to the top of the column to maintain a temperature of 135°F.

The net production passes through a final condenser into a receiver from which normal butane is pumped to storage to be blended later with the cracked and reformed gasoline to bring its vapor pressure up to specifications. The bottom temperature is maintained at 325-350°F. by an external steam-heated reboiler.

The bottoms from the debutanizer flow under system pressure to the rerun column, a 3½-ft. by 42-ft. tower containing 20 trays and operating at five pounds pressure. A top temperature of 225° is maintained by refluxing with a part of the overhead condensate from the receiver at a ratio of 0.1-0.2:1. The bottom temperature of 350-375°F. is maintained by an external steam-heated reboiler.

The overhead from this column is the finished aviation alkylate fraction having the following characteristics:

Quality of Alkylate Produced

Octane Rating A.S.T.M. Clear	91.1
AFD 1 C + 4.6 cc TEL	108.0
AFD 3 C + 4.6 cc TEL	S + 2.46
90% Point	238°F.
End Point	294°F.
RVP lb.	6.5

This material goes to intermediate storage and subsequently is blended into aviation gasoline. The bottoms from the rerun column amounting to less than 10 percent of the total alkylate, is charged to the catalytic cracking unit for further recovery of material boiling below 330-340°F. and cracking of fractions boiling above 400°F.

Modifications in operating procedure which increased the production of 100-octane gasoline by more than 50 percent over what was expected consisted in the following:

The operation was changed in several ways, namely:

(1.) The catalytic cracker was operated to produce more olefins without appreciably reducing the quality of the base stock.

(2.) The gas concentration depentanizer was changed to an alkylate debutanizer to remove a bottleneck in the alkylation operation.

(3.) The gas concentration debutanizer was operated as a depentanizer, removing all the BB and C_5 fractions overhead. Thus the catalytic C_5 fractions containing about 30 percent amylenes could be charged to the alkylation unit along with the BB feed.

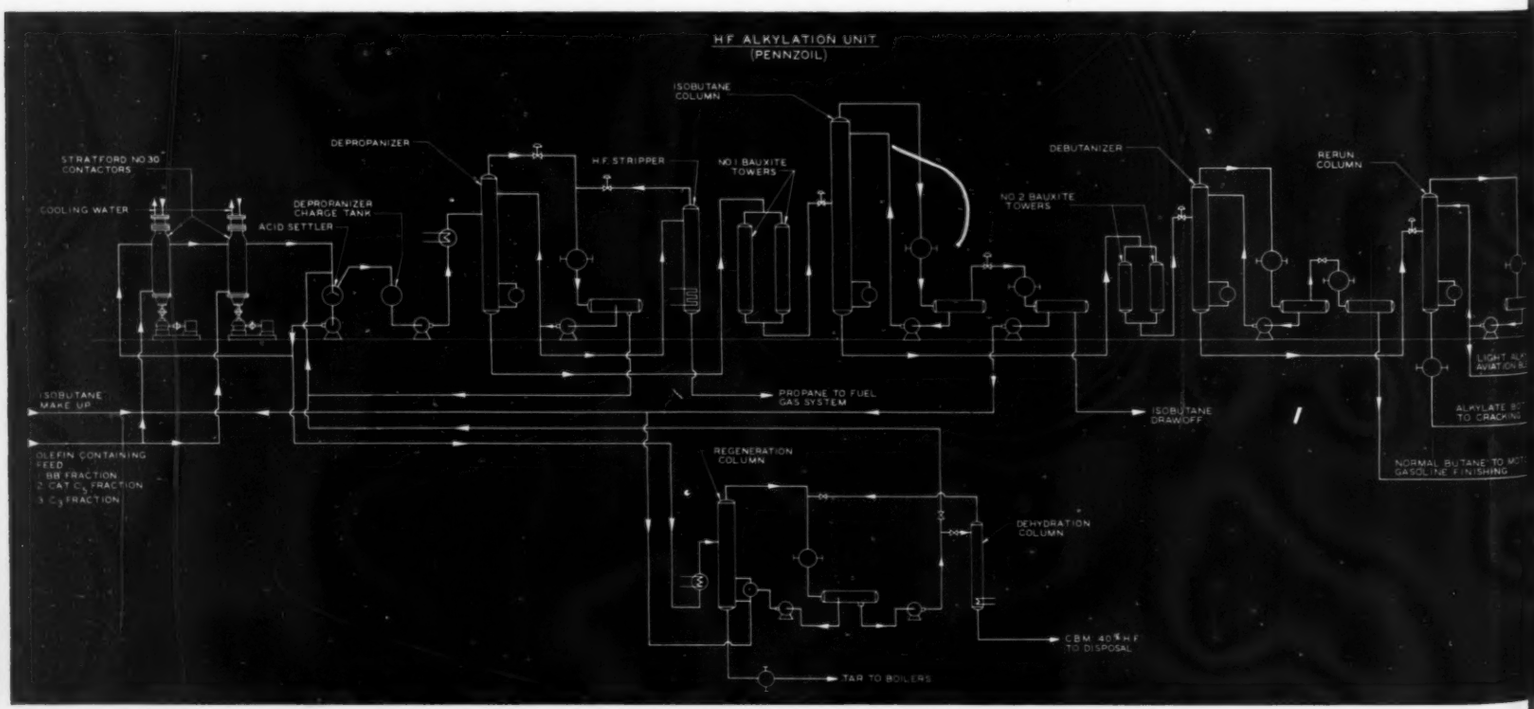
(4.) Isobutane is obtained from outside sources where there is an excess over local requirements, to make up the deficiency, inasmuch as it takes 1¼ barrels of isobutane to one barrel of olefin to produce alkylate.

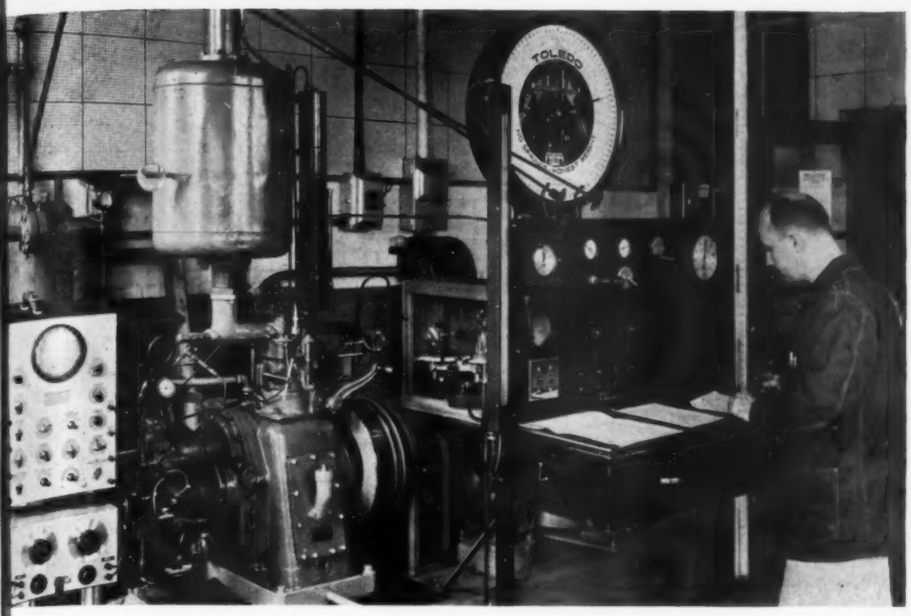
(5.) The increased production of aviation gasoline led to a shortage of isopentane. Isopentane is blended to increase the vapor pressure of 100-octane gasoline. Arrangements were made to obtain about 200 barrels a day of isopentane containing about 30 percent olefins, from another refinery. This material is now charged to the alkylation unit to increase alkylate production and to make up vapor pressure deficiency.

The alkylation unit still is not overloaded and present plans call for increasing the charge of propylene.

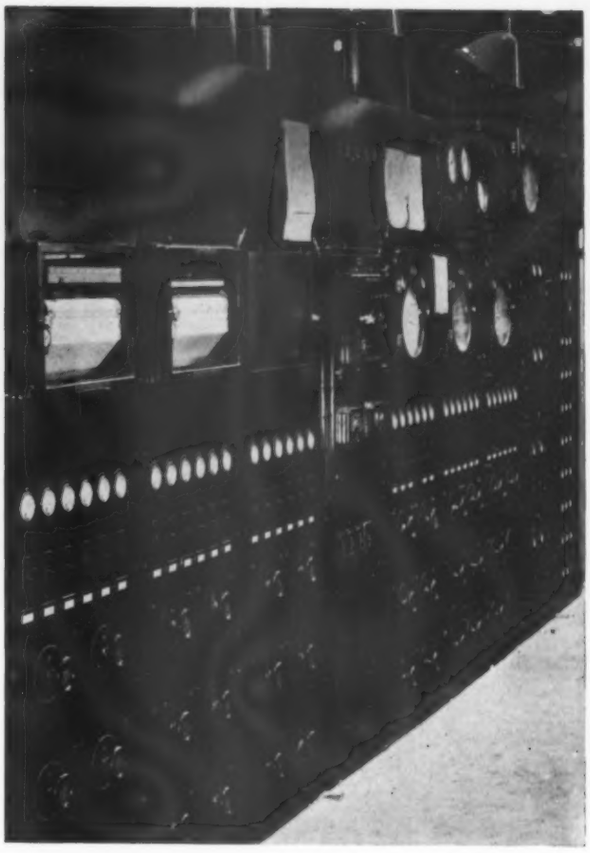
In order to obtain a depropanizer overhead fraction free of all C_2 and lighter hydrocarbons, the low pressure condensate and thermal overhead condensate are to be charged to the deethanizer instead of to the depropanizer of the gas concentration unit. Preliminary operation has already indicated that a C_2-free depropanizer overhead fraction rich in propylene can be recovered with no appreciable increase in BB loss in the deethanizer.

The possibility of installing an isomerization unit in conjunction with the other operations was investigated. However, the production of normal butane in the cracking operations is only sufficient to meet vapor pressure requirements of the motor gasoline and there is not enough casinghead gasoline available at the refinery to make up vapor pressure specifications.





Engine Testing Laboratory—Aviation Fuels.



Control Board Hydroforming Pilot Plant.

SYNTHETIC GASOLINE FROM NATURAL GAS

By Dr. O. W. Willcox

AMONG the numerous matters that are currently pressing themselves upon the attention of the petroleum industry of the United States is the proposition to make commercial gasoline and chemicals out of natural gas by use of the Fischer-Tropsch synthesis.

This proposition has attained imminence by an announcement from a large and experienced firm of oil refinery engineers (M. W. Kellogg Co.) that it is prepared to install this process with assurance to its licensees that where natural gas can be had at the price of five cents per thousand cubic feet—and if other conditions are favorable—the gasoline produced by the Fischer-Tropsch synthesis will compete successfully with the ordinary refinery product under present conditions in the markets for crude oil and motor fuel. Specifically, there is offered a yield of 80 percent of gasoline (presumably based on the primary synthesis product); this gasoline is said to have an octane rating of 75, (motor method) which can easily be raised to 80 by addition of lcc. of tetraethyl lead.

Proposals more or less similar to the Kellogg proposition have appeared in other quarters. The Koch Engineering Company has lately been in the news to the effect that this concern has under consideration a project to build a "synthine" plant to utilize natural gas in the Kansas-Oklahoma area in cooperation with a local refinery. Equally to the point is a statement from the president of the Standard Oil Development Company that this concern is about ready with its own version of the Fischer-Tropsch process; it is believed that when this process is finally licked into shape the produced gasoline will be able to compete with the conventional product. According to the statement as reported in the trade press, Fischer-Tropsch gasoline can be made from natural gas at a cost of 4.8 cents a gallon. This may be compared with the current estimate that the average cost of making gasoline by thermal cracking of crude is 5.3 cents a gallon, with a crude oil price of $1.25 a barrel.

The Kellogg proposition contemplates not only the conversion of natural gas into gasoline, but also into a wide range of hydrocarbon products for the use of manufacturers of chemicals and may even include oxygen-containing organic compounds. These chemical materials may be either by-products of the main gasoline synthesis, or they may be purposely synthesized as a side line of greater or less importance depending on circumstances. As many of these subsidiary products are higher priced than gasoline, the extra values thus obtained may help to make the process as a whole more profitable, though it is insisted that these secondary products have not been taken into account in determining the feasibility of the Kellogg version of the Fischer-Tropsch gasoline synthesis.

If we take it for granted that the profitable conversion of natural gas to motor gasoline and chemicals has become a commercial actuality, it is evident that the petroleum industry is about to take an important new turn in association with the natural gas industry. The proposition by Kellogg is specific in that it promises immediate profit under conditions where natural gas can be had at 5 cents a 1000 cubic feet, even in the face of competition from gasoline made from crude oil at $1.25 a barrel. And, looking toward the future, it does not appear that the present situation is likely to turn unfavorable to the Fischer-Tropsch product, but rather the reverse. It is a nearly unanimous opinion in the petroleum industry that the present price of crude oil, now held down by governmental pressure as a counter-inflationary measure, is too low. The cost of producing crude oil has been steadily rising against the governmentally pegged price, and whether the materials and labor costs involved in oil production will be appreciably decreased on the return of peace is doubtful. A strong indication that the future price of crude oil must increase is given by the fact that the average oil well now has to be drilled deeper, which, of course, materially increases cost of production. Also, the cost of producing crude oil is continually increasing on account of the difficulty of discovering new fields to take the place of those approaching exhaustion. For the past seven years new oil has been discovered at a diminishing rate, and in 1943 the petroleum industry of the United States actually found less new oil than it consumed in that year, notwithstanding extraordinary efforts by the exploration departments of all the country's oil enterprises. During January, 1945, no less than 522 geophysical crews were in the field, against around 200 a few years back. These crews are now finding more new oil fields than ever, but the fields are generally small and relatively unproductive, so that the new oil costs more. According to some petroleum statisticians the cost of finding new

oil is now one-fifth or more of the total cost of producing it.

All these circumstances point to a nearly inevitable rise in the future price of crude oil, and as the price of crude rises above $1.25 a barrel the competitive position of Fischer-Tropsch gasoline will be proportionally improved.

Should the price of crude go no higher than $2.00 (which is by no means inconceivable) it appears certain that the market position of Fischer-Tropsch gasoline from natural gas would be very solidly established, unless at the same time the price of natural gas is disproportionally increased, which at present does not appear likely. Under existing conditions, a market is not available for all the natural gas that can be made available, even for fuel; many gas fields remain without pipe line connections with consuming centers that are already well supplied. The unavoidable result is much wastage in the more remote fields. It has been estimated that in Texas alone the waste of casing head flare gas is a billion cu. ft. a day, and this situation is prompting still more stringent laws restricting the allowable gas-oil ratios for Texas oil wells. The available market for natural gas also suffers the disadvantage that consumption of this fuel is seasonal, so that less gas is marketable during the summer. These inconveniences would be considerably alleviated if Fischer-Tropsch plants were available to absorb the excess of local gas production.

Interest in recent developments relating to the Fischer-Tropsch synthesis is not confined to the petroleum industry. Komarewsky and Riesz of the Institute of Gas Technology have pointed out what Fischer-Tropsch may mean to the manufactured gas industry which produces about 10 percent of all fuel gas marketed in the United States. The basic product of this industry is water gas, which is a mixture of carbon monoxide and hydrogen—exactly the same primary product that is produced when the Fischer-Tropsch process is applied to the methane of natural gas. The suggestion here is that the manufactured gas producers, who are already greatly skilled in the production of the primary carbon monoxide and hydrogen mixture, may well take the additional step of applying the Fischer-Tropsch synthesis to this mixture and thus themselves produce the enriching hydrocarbons for which they are now dependent on the regular petroleum industry. This would place in their hands a means of upgrading manufactured gas, and also a means of employing their manufacturing plants at something approaching capacity the year around. The idea here is to manage the synthesis so as to produce considerable proportions of the lighter hydrocarbons (C_3 and C_4) which can be readily stored and used to enrich the gas and to supplement peak loads. The higher and more valuable products such as isobutane and other iso-paraffins, iso-butene and other butenes, high-melting wax and oxygen-containing compounds, might be sold to chemical manufacturers. These activities are at present held out to the manufactured gas industry as possibilities only, subject to future developments in this newly opened field.

As a matter of fact, the petroleum industry is already committed in a large way to the manufacture of organic chemicals as a subsidiary line. The immediate prewar period witnessed an extensive use of hydrocarbon materials produced or producible from petroleum in the manufacture of solvents, ethyl alcohol, plastics, nylon, etc., and a good beginning had been made in the production of special rubber substitutes. With the coming of World War II the chemicals division of the oil refining business underwent a great expansion. Organic compounds, the preparation of which involved complicated process of synthesis and purification, were demanded for the production of toluene for explosives, the essential ingredients of 100-octane gasoline, synthetic rubbers, and a considerable variety of accessory materials. Along with this stupendous effort to produce chemical materials for war, some oil refineries have found it possible and on the whole profitable to transform selected hydrocarbons into many chemical products not exclusively related to war purposes, such as formaldehyde, acetaldehyde, methanol, ethanol and higher alcohols, glycols, acetic acid and its derivatives, carbon disulfide and tetrachloride, solvents, detergents, and a very long list of other organic chemicals. Thus the petroleum refining industry is even now deeply engaged in the chemical business, and on a volume basis is even producing more organic chemicals than all the regular chemical industry itself. To be sure, relatively great as it is, the organic chemical branch of the oil refining industry represents only a small fraction of the total refinery output but the oil companies which have embarked on this line must be regarding it as worthwhile, because they are taking steps to enlarge their operations and to fortify their technological and commercial position in it for the post war era. For instance, the Shell Oil Company and the Standard Oil Company of New Jersey maintain complete organizations for the manufacture and distribution of their chemical products. Others, like The Texas Company and the American Cyanamid Company, have combined their special facilities for production of industrial petroleum chemicals; in this case a new jointly-controlled company—the Jefferson Chemical Co., Inc.—will handle the chemical business of these two oil companies. The Phillips Petroleum Company and the Continental Oil Company are said to have a similar joint arrangement.

A part of the reason why chemical manufacturing is being given the status of a separate entity is that the processes are no longer simple. Heretofore it sufficed to produce the primary hydrocarbons by close fractionation in the ordinary course of distilling operations. But the supply of cracked refinery gases is proving insufficient to meet the needs of chemical industry, and it is becoming necessary to invoke special catalytic and high pressure techniques of pyrolysis, nitration, chlorination, and other manipulations of industrial chemistry.

Meanwhile, the regular chemical companies are also moving in to get their share of the business of producing organic chemicals from petroleum. The Dow Chemical Company has a 79-mile 4" pipe line to its chemical plant in Freeport, Texas, for transporting the lighter petroleum fractions from the casing heads for conversion into finished or intermediate products. Late in 1944 PAW authorized three projects at recycling plants for supplying major chemical companies with ethane and propane for certain organic synthesis, and it is said that four other major chemical concerns have been seeking ethane and propane for undisclosed purposes.

However, in all this activity in the field of petroleum chemicals it will be well to keep in mind that on the most optimistic estimate the amount of raw hydrocarbon material that can be diverted to this line is a small fraction of the total demand for petroleum products. The prime function of the oil refining industry is and will remain the production of automotive fuel, lubricants and fuel oil. An installation built to work on natural gas by the Fischer-Tropsch process must mainly depend for survival on its ability to make a profit on a large output of gasoline. Any profit from the sale of chemicals will be proportionally small, first, because of the present relatively small volume of this business in comparison with the gasoline business and, secondly, because of competition from enterprises that are already in or are preparing to enter the field of petroleum chemicals. The market for chemicals is large, but the petroleum industry has at its disposal enough raw materials to swamp this market many times over. In offering its perfected Fischer-Tropsch process to the refining industry the Kellogg Company has been very careful to emphasize this competitive situation. The claim is made, however, that the Kellogg process can stand entirely on its ability to produce gasoline at a profit on 5-cent natural gas under favorable conditions. Any extra profit that comes from subsidiary chemical products is just that much to the good.

The Kellogg people also make it clear that the slogan "gasoline from 5-cent natural gas," while meaning just that, contemplates an outer boundary or "ceiling" for the proposition. It may be that a refiner could well use 5-cent natural gas to make gasoline, but the proposition is seen at its best when the process is regarded as a tool by which reserves of natural gas, now unsalable as much, may be converted into gasoline, which has a far wider market, with chemicals on the side. Not all owners of natural gas reserves are

(*Continued on page 120*)

Alkylate Unit With 100-Octane Blending and Storage at Right.

Thermal Cracking Plant Revamped For Catalytic Operations

THE old adage that "in union there is strength" has been demonstrated by a cooperative oil cracking enterprise founded by four neighboring small refineries in Pennsylvania in 1931. These concerns are the Pennzoil Company, the Quaker State Oil Refining Corporation, the Wolf's Head Oil Refining Company and the Continental Refining Company. These four companies joined their forces to install a 2500-barrel-per-day single coil UOP thermal cracking unit for their common use. This unit was installed on the premises of the Pennzoil Company, and the Pennzoil Company operated it for the joint account of the four participating companies. Each participating refinery supplies its proportionate share of cracking stock, bears its share of the costs, and takes its share of the products. These relations were not embodied in a jointly owned corporation, or even a formal partnership. The obligations and rights of the participants are defined by mutual understanding set forth in a simple contract. The four companies, on taking their shares of the jointly owned cracking unit, retained complete freedom of commercial action, they were and have remained to this day competitors in the market for oil products. But after nearly fifteen years they are still cooperating amicably and successfully. Thus they have furnished a demonstration of the fact that small refiners can remain competitors and still by joint action obtain the benefits of modern facilities that might be too costly for any of them to obtain from their limited capital, and to effect economies that no one of them could accomplish alone.

The jointly operated 2500-barrel single-coil cracking unit installed in 1931, which was known as Dubbs No. 3 at the Pennzoil refinery, was converted in 1938 to 2-coil operation and its capacity raised to 4500 barrels per day. In the following year the associated refiners, still pursuing their plan of obtaining the benefits of joint action in refinery operation, installed a 200-barrel-a-day UOP catalytic polymerization unit to polymerize the olefins from the thermal cracking unit, thus increasing the over-all yield of gasoline from the crude oil and improving its octane rating.

About that time the process of catalytic cracking had made its entry into petroleum refining, and had demonstrated its ability to produce high quality gasoline. Events were moving toward Pearl Harbor and war, which would create a great need for aviation gasoline. The four associated refiners, now habituated to common action to obtain benefits of modern technology that would remain beyond their single reach, decided to install a cooperative catalytic cracking unit. Their primary objective was to put their jointly operated refinery facilities effectively into the war effort as a producer of aviation gasoline; beyond this the primary objective was the purpose of fortifying the post-war positions of the associated companies in the gasoline market by acquiring the ability to meet any high octane standards that might come to be set for post-war automotive fuel. Each of the four companies put up their shares of funds to pay for the new catalytic cracking unit.

Out of this unit there has grown a 100-octane gasoline plant which has now developed far beyond the original plan, but is still operated for the common purpose. It comprises the three elements that make up a complete aviation gasoline refinery, namely, a single-stage fluid catalytic cracker of 4500 barrels daily capacity, a gas concentration unit, and a UOP HF alkylation unit designed to produce 740 barrels per day of alkylate. The catalytic cracking unit, together with the auxiliaries and necessary alterations to other process units, cost the co-owners more than $2,000,000 and the gas concentration and alkylation units with their auxiliaries cost well over $3,000,000 more. These last named facilities were financed by the Defense Plant Corporation and are operated by Pennzoil under contract with the government. These combined facilities are today actually turning out 50 percent more of 100-octane gasoline than they were originally expected to produce.*

It was their previous experience as cooperators that gave the co-owners of this relatively small but efficient enterprise the confidence to venture together into the war production program. Their success may well be an example for other similarly situated small refining companies.

The original cooperative unit, Dubbs No. 3, was the starting point in the war conversion program although it had made a small pre-war contribution to the aviation gasoline supply by con-

**A description of this aviation gasoline plant is given in a separate article.*

verting the polymerization unit from motor polymer to codimer production.

Dubbs No. 3 is said to be the first UOP thermal cracking unit ever to be tied into a catalytic cracking operation. Here is the way it was done. The fractionator, which had almost reached the retirement stage for high pressure operation, was found to be of suitable size to serve, with minor changes, as the fractionator for the catalytic cracker. So it was moved to the proper location and placed in a service which requires an operating pressure of only five pounds. A new tower, designed for 90 pounds pressure, was installed on the thermal cracker.

It was evident that under the new scheme, the thermal cracker would lose its old job, because the gas oil and kerosene formerly charged to it would go to the catalytic cracker instead. The only material available for thermal cracking would be catalytic cycle stock, amounting to 1500-2000 barrels per day, and straight-run gasoline.

It was found that the original 2-cell heavy oil heater of the thermal cracker, a 45,000,000 Btu/hr. furnace, had sufficient capacity to handle all the catalytic cycle stock. Two-coil operation could be carried out by merely separating the coils, using one side for light and one for heavy oil. This was done, giving the unit a capacity of about 2500 barrels a day and effecting a substantial economy.

Through this arrangement, the light oil heater, a 30,000,000 Btu/hr. furnace, was released for use, without being moved from its original location, as a heater for the feed to the catalytic cracker.

A UOP center wall updraft reforming heater, of 3500 barrels daily capacity, was added, so that the reforming of straight-run gasoline and cracking of cycle stock could be done in a single unit, thereby economizing on manpower and operating costs.

The remodeling of Dubbs 3 was carried on in such a manner that its operation was interrupted for only two months.

In its new role today, this thermal unit is cracking about 1600 barrels per day of cycle stock and 2500 barrels per day of straight-run gasoline. The former is produced in the catalytic cracking unit. The gasoline comes from the refineries of Pennzoil, which, as before mentioned, is the maker of "Pennzoil" motor oil; Quaker State, manufacturer of "Quaker State" motor oil; Wolf's Head, producer of "Wolf's Head" motor oil, and Continental, manufacturer of "Coreco" motor oil.

The cycle stock is pumped directly from the fractionator of the cat cracker into the thermal cracker fractionator, which operates at a top temperature of 370°F., bottom temperature of 615°F., and 93 pounds pressure. Heavy combined feed from the bottom of the fractionator is charged to the heavy oil side of the heater and light combined feed, as a side cut from the fractionator, is charged to the light oil coil.

Heat is recovered from the fractionating column by circulation of side-cut and bottoms through steam-generating heat exchangers, which together produce 18,000 pounds per hour of 125-pound steam. This method of heat recovery was installed as the economical way to relieve the load on an old and overtaxed boiler plant.

The heavy oil stream leaves the heater coil at a transfer temperature of 915°F. and goes into the top of the reaction chamber which operates at 375 pounds pressure. The light oil stream leaves the coil at 945°F. and joins the heavy oil stream at the reaction chamber outlet, ahead of the pressure control valve.

Vapors from the reformer, leaving the heater at transfer temperature of 975-1000°F. and at a pressure of 500 pounds, are quenched with light oil to a temperature of 800°F., passing through a pressure control valve and joining the other streams at the primary flash chamber inlet.

Overhead from the primary flash chamber enters the fractionator at a point below the inlet of the cycle stock. Primary flash chamber bottoms go to a secondary flash chamber operating at 30 pounds pressure and 525°F. temperature. Overhead from the secondary flash chamber is used as transfer quench and flash chamber reflux. Bottoms from the secondary flash chamber, black fuel oil of 10° A.P.I. gravity, represent about 10 percent of the gasoline-cycle stock charge.

Feed to Dubbs No. 3

Straight run gasoline	360 e.p., 52 octane number
Catalytic cycle stock	36-37° A.P.I. gravity, 400°F. I.B.P. 650°F. end point

Products From Dubbs No. 3

	Vol. %	Bbl./day
Motor gasoline fractions, 400°F. end point, 64-65 octant rating, 5-6 lb. RVP	72-77	2900-3100
Butylenes	5	200
Isobutane	1.5	60
Bottoms	10	410
Gas	9-12	—

Overhead from the fractionator goes to a receiver where liquid and gas are separated. A 2-cycle 200 h.p. gas-engine driven Clark compressor compresses the gases from 90 to 225 pounds, and delivers them to the de-ethanizer of the gas concentration system for the recovery of C_3 and heavier hydrocarbons.

Unstabilized gasoline from the receiver goes to a pair of stabilizers operating in parallel as a debutanizer. The overhead condensate is charged to the depropanizer of the gas concentration system. The bottoms are debutanized motor gasoline fractions.

The butylenes and isobutane recovered make up a part of the charge to alkylation; thus, the thermal unit has a substantial part in the production of aviation gasoline, as well as in converting cycle stock and straight-run into motor gasoline.

Catalytic naphtha from the bottom of the rerun column of the gas concentration system, and motor polymer when available, are blended with the thermally cracked and reformed motor gasoline and its vapor pressure is raised to specifications by the addition of normal butane recovered from the thermal and catalytic BB fractions and separated in the debutanizer of the alkylation unit.

The catalytic polymerization unit, which was robbed of its normal feed in the new arrangement, was modified so that it could process the gas concentration depropanizer overhead to produce motor polymer. This was accomplished by combining the depropanizer overhead and the normal butane stream from the alkylation unit debutanizer in the poly unit feed drum, providing a liquid feed which can be processed without extensive alterations to the existing equipment. Normal butane thus recovered is combined with the debutanized motor gasoline components along with the polymer.

Although the processes that take part in the production of aviation gasoline are interdependent, top honors for usefulness probably should go to the fluid catalytic cracking process because it is the largest producer of the components of 100-octane gasoline.

Those components are base stock, alkylate, and isopentane. The catalytic cracker produces all the base stock, most of the isopentane, and the greater part of the isobutane and butylenes which go to make up alkylate. In one method of operation, the cat cracker has produced from a virgin feed of 4300 barrels a day, these vital products:

Depentanized 330°F. end point base stock	875 barrels	20.3 vol. %
C_5 fraction	460 "	10.7 " "
Butylenes	325 "	7.5 " "
Isobutane	460 "	10.7 " "

The 4500-barrel daily design capacity of the catalytic cracker was based on a charge composed of 3900 barrels of gas oil of 39-40 A.P.I. gravity and 600 barrels of kerosene of 45 A.P.I. gravity. It was expected that the gas oil and kerosene produced in the Pennzoil plant and in those of the co-owners would be sufficient to supply the feed stocks in that ratio and in the quantities needed.

Owing to shortage of Pennsylvania crude, that condition has not prevailed. Consequently, it has been necessary to purchase gas oil from other sources.

Under these conditions the catalytic cracking unit has demonstrated its versatility. When sufficient fresh feed stock was available, the unit had cracked as much as 5000 barrels per day. It has run on charges ranging from straight gas oil to mixtures containing up to 30 percent kerosene, taking them in stride. Even Illinois gas oil as low as 33° A.P.I. gravity has been cracked without difficulty and with no serious effect on yields.

Operating conditions have been varied as much as charging stocks to meet special requirements. For instance, since isobutane became available from outside sources, the reactor temperature has been progressively increased to 950°F. in order to produce at the same time the maximum amount of butylene for alkylation and a base stock suitable for aviation blending without treatment other than a caustic wash.

During periods when output of 100-octane gasoline is limited by shortage of alkylate, the overall production has been increased by improving the quality of the base stock in a partial retreating operation in which 400°F. endpoint gasoline from the receiver is returned to the reactor along with the fresh feed.

Sidecut or cycle stock from the fractionator, which usually is cracked in Dubbs No. 3, has been recycled to the catalytic reactor in order to maintain maximum yields of base stock during periods when the supply of virgin charge stock was insufficient.

For instance, during the first two weeks in February, 600-700 barrels per day of recycle gasoline was charged to the unit, together with 4000-4200 barrels of virgin gas oil in order to improve base stock quality. Late in February, the operation was changed. Instead of recycling raw gasoline, 750-850 barrels per day of sidecut cycle stock was charged to the unit with 4300-4400 barrels of fresh gas oil, in order to increase the overall production of aviation gasoline.

When sufficient fresh feed stock again became available, recycling was stopped and the charge of fresh feed was increased to 4800-5000 barrels per day.

Yields from the operation when processing 3800 barrels per day of virgin gas oil and 700 barrels per day of sidecut cycle stock (calculated on fresh feed input basis) were:

Debutanized base stock	36.4 Vol. %
Naphtha	7.1 " "
Light gas oil (cycle stock)	23.6 " "
Total C_4 fraction	26.4 " "
C_3 and lighter gases	12.8 Wt. %
Coke	5.9 " "

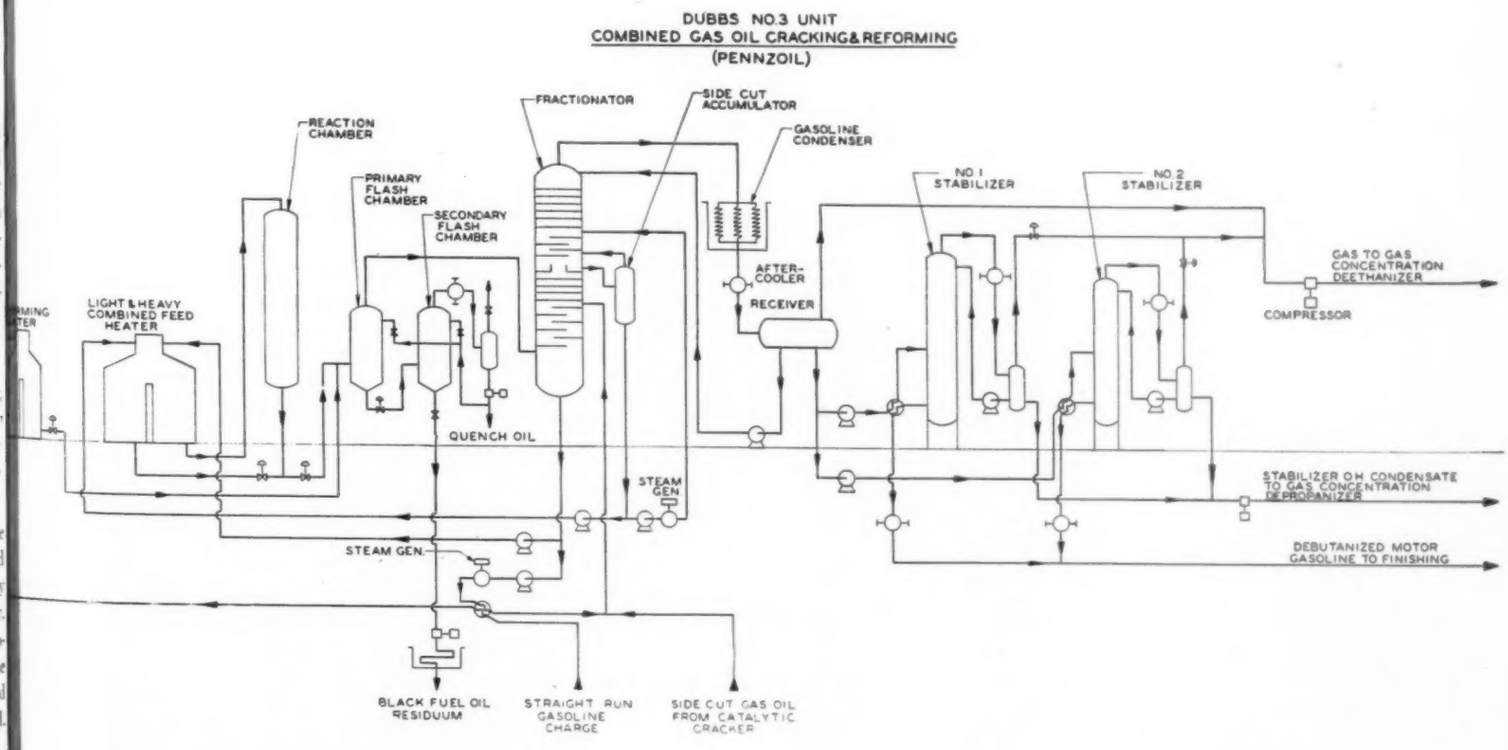
Normal Feed Stock and Quality of Products

Type:	Gas Oil	Fresh Feed	Debutanized Base Stock	Heavy Naphtha	Light Gas Oil
Gravity		39.0	66.0	37.4	37.5
A.S.T.M. Dist.					
I.B. P. °F.		387	99	338	412
10		492	116	349	485
50		575	155	360	530
90		658	284	370	600
E.P.		705	327	417	665
Sulphur Wt. %		0.01			
Reid V.P.		9.1			

	Debutanized Base Stock
Octane number	
AFD-1C clear	80.8
AFD-1C + 4.6 cc TEL	91.1
AFD-3C + 4.6 cc TEL	5 + 0.37

Composition C_4 Fraction Liquid

	Vol. %
Isobutylene	12
Normal Butylene	24
Isobutane	53
Normal Butane	11



ADAPTATION OF REFINERY OPERATIONS TO CHANGING POST-WAR CONDITIONS

By E. R. Smoley and V. O. Bowles
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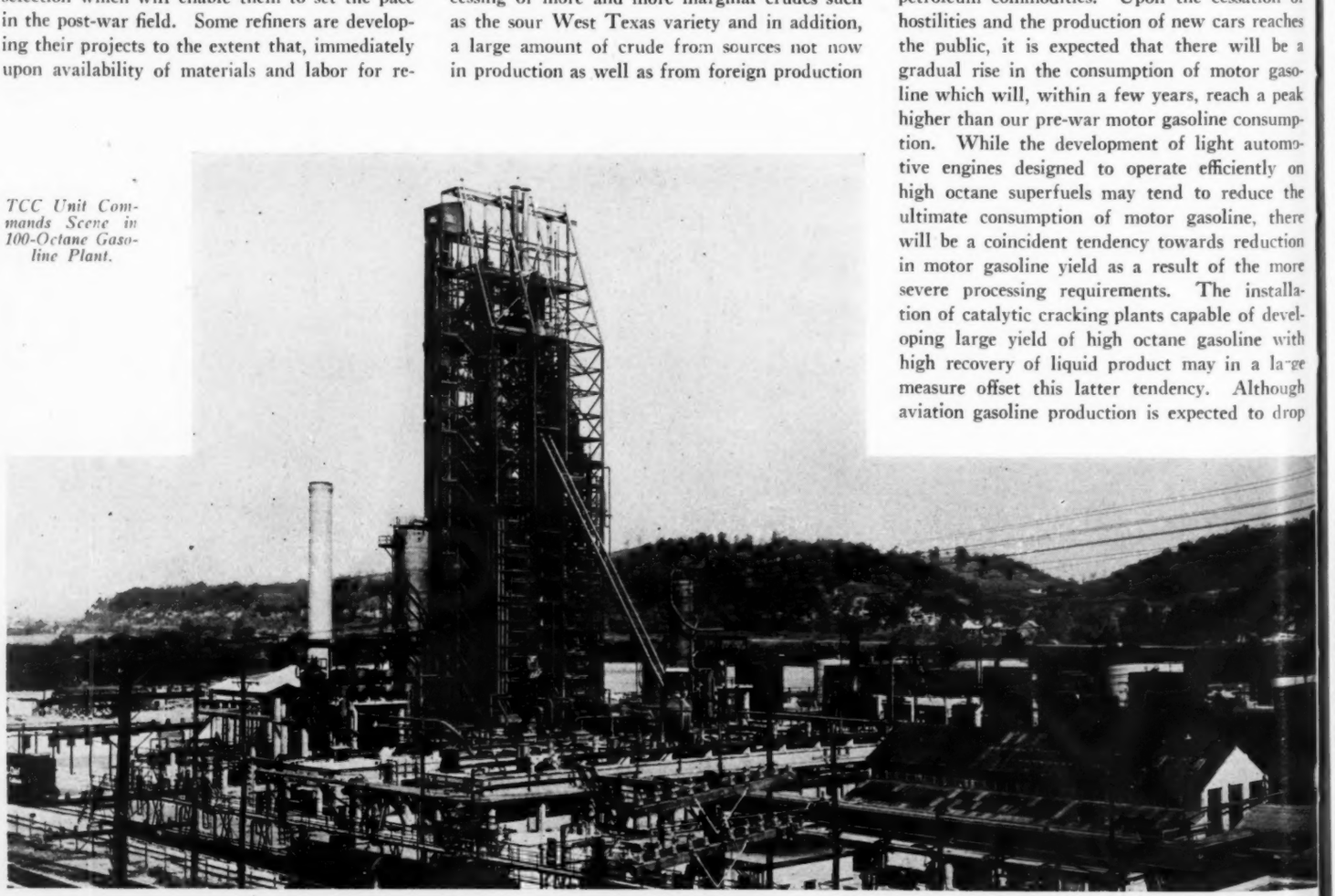
IN general, petroleum refiners have two types of problems before them at the present time. First, the refiner who has installed catalytic cracking facilities, alkylation units, isomerization plants, and superfractionating equipment, as well as other related processing equipment, which were not planned for post-war refinery marketing situations, is faced with the problem of developing economical competitive refining operations with the increased facilities he now has available. In many cases, it may prove very desirable to modify these war plants to make them more suitable for postwar operation as well as to install additional facilities to permit the most economical manufacture of required products. Second many refiners, because of their geographic location, financial structure and other reasons, have not installed extensive war commodity manufacturing facilities and therefore, at this time, are faced with the possibility of not being able to meet the post-war competition offered by refiners who have installed such facilities. While this situation may appear to be a disadvantage to these refiners, many of them are already proceeding to turn this handicap into an advantage by immediately laying their plans for the installation of modern facilities designed for the most economical manufacture of post-war petroleum products. These refiners at the present time are making intensive studies of the available processes to determine the optimum selection which will enable them to set the pace in the post-war field. Some refiners are developing their projects to the extent that, immediately upon availability of materials and labor for refinery construction work, they will be ready to place orders for equipment.

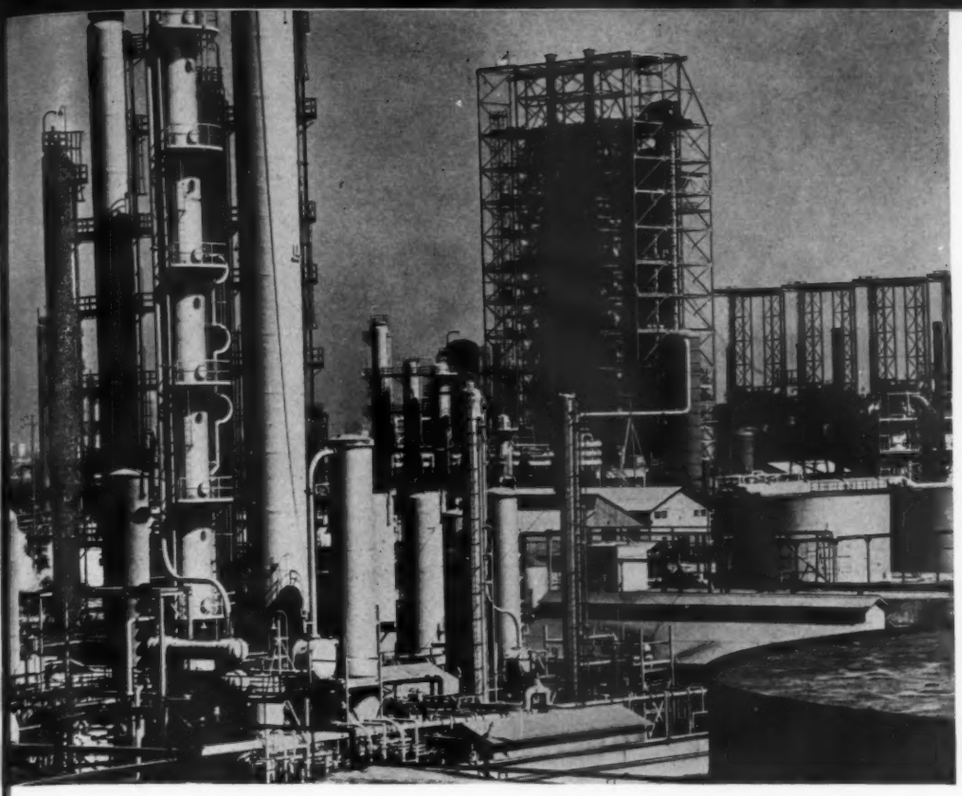
This paper, as the title indicates, is intended to outline general considerations and stimulate thinking in an attempt to be helpful to the refiner in his post-war planning. As every refiner appreciates, any planning is exceedingly complicated because of the many uncertainties and variables with regard to crude situations, marketing requirements, and available process methods which have been greatly improved and expanded during the war years. The discussion presented in this paper is of necessity general in nature since the development of any refinery post-war plan involves consideration of the above uncertainties and variables which will differ widely for each specific case.

It is anticipated that the daily crude runs in the United States will increase to thruputs exceeding the maximum during the war years, in order to meet the demand for post-war motor gasoline, diesel fuels, and heating oils, as well as for private and commercial aviation gasoline. This anticipated increase in crude runs coupled with decreases in crude availability from existing sources of production will necessitate the processing of more and more marginal crudes such as the sour West Texas variety and in addition, a large amount of crude from sources not now in production as well as from foreign production fields. It is difficult, therefore, for refiners who contemplate additional crude runs or who expect to be faced with a shortage of crude from existing sources to appraise accurately a future crude situation. However, there is a general tendency toward the processing of more and more high sulphur crudes such as West Texas and the like and toward producing lower gravity crude from presently producing fields. Furthermore, seaboard refiners anticipate processing substantial quantities of crude from South America and possibly from the Near East. Frequently, these foreign crudes also are characterized by high sulphur content and are relatively low in gravity. While the character of many of these foreign crudes is fairly well established, the problem of processing foreign crudes is further complicated by such situations as that prevailing in Venezuela, where there appears to be a strong move towards limiting crude export and forcing oil companies to build new refineries in Venezuela and employ Venezuela labor for the operation of these refineries. Such projects as this will, of course, offset to some extent the requirements for increased domestic crude runs.

An accurate appraisal of the post-war market for refined petroleum products is obviously very difficult at this time, although it is possible to make certain qualitative predictions regarding production, quality and specifications of post-war petroleum commodities. Upon the cessation of hostilities and the production of new cars reaches the public, it is expected that there will be a gradual rise in the consumption of motor gasoline which will, within a few years, reach a peak higher than our pre-war motor gasoline consumption. While the development of light automotive engines designed to operate efficiently on high octane superfuels may tend to reduce the ultimate consumption of motor gasoline, there will be a coincident tendency towards reduction in motor gasoline yield as a result of the more severe processing requirements. The installation of catalytic cracking plants capable of developing large yield of high octane gasoline with high recovery of liquid product may in a large measure offset this latter tendency. Although aviation gasoline production is expected to drop



TCC Unit Commands Scene in 100-Octane Gasoline Plant.



Fractionation and TCC Units (Right) in High Octane Refinery.

to about one-fifth of the peak war production which value is considerably more than pre-war production of aviation gasoline, it is not likely that this will have any effect on the increasing trend of motor gasoline consumption.

The installation of extensive facilities for the production of 100 octane aviation gasoline throughout the country will undoubtedly be reflected in a sharp increase in regular and premium grade motor gasoline octanes as soon as the war requirement of aviation gasoline is curtailed. It is expected that house brand octane numbers will increase to as high as 80 MM octane number and that the octane number of premium grade gasoline will increase to as high as 85 within a few years after the close of the war. Considerable importance will be attached to research method octane specification since this more accurately reflects certain phases of road performance. Catalytic cracking and naphtha polyforming operations are both characterized by large spreads between motor method and research octane values and will be valuable tools in meeting high research octane requirements. As a matter of fact, there are a considerable number of refiners who will be immediately in position to produce gasoline of these qualities as soon as their catalytic cracking, alkylation and other facilities are no longer required for the production of 100 octane aviation gasoline for the war effort. These refiners will be in good position to profitably curtail reforming operations and tetraethyl lead addition while at the same time setting the octane pace. On the other hand, other refiners, not so fortunate, will have to extend naphtha reforming operations and increase tetraethyl lead additions to the point that refinery modernization through the installation of catalytic cracking and other facilities will become so attractive comparatively that they can no longer delay action on such projects.

By the end of 1941 approximately 20 Houdry catalytic cracking plants were either in operation or under construction. These Houdry units were operated largely by the two refining companies who control the process and at that time there were no other catalytic cracking processes in commercial operation. At present there are approximately 88 catalytic cracking units in operation employing four different processes with a total combined post-war gas oil charging capacity of more than one million barrels per day. These catalytic cracking plants are capable of producing close to 50 percent of the gasoline made from thermal cracking units before the war. While most of these catalytic cracking units are located in large refineries, some are in small plants and studies indicate that the small refiner can well afford to buy and operate a small catalytic cracking unit since the installation cost per barrel of charge is not significantly greater than for the very large units. It is possible to install catalytic cracking plants in sizes as small as 2,000/B/D economically so that the small refiner who runs 7,000 to 10,000 barrels of crude per day will find that the increased returns resulting from higher liquid recoveries and higher octane ceiling on motor gasoline may well justify the installation of a small catalytic cracking plant.

The following tables list the Houdry, TCC, Fluid and Cycloversion plants with their conservative post-war gas oil charge rating.

Houdry Catalytic Cracking

	No. Cases	No. Units	Approx. B/D Gas Oil Charge
Gulf Oil Corp., Port Arthur, Texas	6	1	10,000
Magnolia Petroleum Co., Beaumont, Texas	23	4	45,000
Sinclair Refining Co., Corpus Christi, Texas	6	1	10,000
Sinclair Refining Co., Houston, Texas	6	1	11,000
Socony-Vacuum Oil Co., Augusta, Kansas	6	1	10,000
Socony-Vacuum Oil Co., Brooklyn, N. Y.	6	1	10,000
Socony-Vacuum Oil Co., Buffalo, N. Y.	6	1	10,000
Socony-Vacuum Oil Co., East Chicago, Indiana	4	1	10,000
Socony-Vacuum Oil Co., E. St. Louis, Ill.	6	1	10,000
Socony-Vacuum Oil Co., Paulsboro, N. J.	6	1	10,000
Socony-Vacuum Oil Co., Trenton, Michigan	6	1	10,000
Southport Petroleum Co., Texas City, Texas	6	1	11,000
Standard Oil Co. of California, El Segundo, Cal.	6	1	15,000
Standard Oil Co. of Ohio, Cleveland, Ohio	9	2	22,000
Sun Oil Company, Marcus Hook, Pa.	39	5	88,000
Sun Oil Company, Toledo, Ohio	12	1	19,000
Tide Water Assoc. Oil Co., Bayonne, N. J.	12	1	17,000
Total	165	25	318,000

Thermofor Catalytic Cracking

	No. Units	Approx. B/D Gas Oil Charge
Ashland Oil & Refining Co., Catlettsburg, Ky.	2	19,000
Continental Oil Company, Ponca City, Oklahoma	3	29,000
Crown Central Petroleum Corp., Houston, Texas	2	19,000
General Petroleum Corp., Torrance, California	4	40,000
Gulf Oil Corporation, Port Arthur, Texas	3	27,000
Magnolia Petroleum Company, Beaumont, Texas	2	20,000
The Pure Oil Company, Nederland, Texas	2	19,000
Richfield Oil Corporation, Watson, California	2	30,000
Sinclair Refining Co., Houston, Texas	1	10,000
Socony-Vacuum Oil Co., E. St. Louis, Illinois	1	10,000
Socony-Vacuum Oil Co., Paulsboro, N. J.	1	11,000
Standard Oil Co. of California, Richmond, California	2	28,000
Sun Oil Company, Marcus Hook, Pennsylvania	2	22,000
Tide Water Assoc. Oil Co., Bayonne, N. J.	1	11,000
Union Oil Company, Wilmington, California	2	30,000
Total	30	325,000

TCC Plant--In Foreground is Unit's Furnace and Stack.

Fluid Catalytic Cracking

	No. Units	Approx. B/D Gas Oil Charge
J. S. Abercrombie-Harrison Oil Co., Sweeny, Texas	1	15,600
Associated Refiners Inc., Duncan, Oklahoma	1	11,200
Atlantic Refining Co., Atreco, Texas	1	14,000
Atlantic Refining Co., Philadelphia, Penna.	1	14,000
Cities Service Refining Corp., Lake Charles, La.	3	45,000
Cooperative Ref. Assn., Coffeyville, Kansas	1	4,000
Eastern States Petroleum Co. Inc., Houston, Texas	1	5,000
Frontier Refining Company, Cheyenne, Wyoming	1	2,600
Humble Oil & Refining Co., Baytown, Texas	2	28,800
Pan American Petroleum Corp., Texas City, Texas	1	15,500
Pennzoil Co., Oil City, Pa.	1	4,200
Republic Oil Ref. Co., Texas City, Texas	1	11,500
Root Petroleum Co., El Dorado, Arkansas	1	4,500
Shell Oil Company, Wilmington, California	1	15,500
Shell Oil Company, Wood River, Illinois	2	31,000
Sinclair Refining Company, Sinclair, Wyoming	1	8,500
Standard Oil Co. of Indiana, Wood River, Ill.	1	10,000
Standard Oil Co. of N. J., Baltimore, Md.	1	15,500
Standard Oil Co. of N. J., Baton Rouge, La.	3	44,300
Standard Oil Co. of N. J., Bayway, N. J.	1	11,500
The Texas Company, Port Arthur, Texas	2	31,000
The Texas Company, Wilmington, California	1	16,300
Tide Water Assoc. Oil Co., Avon, California	1	16,000
Utah Oil Refining Co., Salt Lake City, Utah	1	8,500
Wilshire Oil Co., Norwalk, California	1	4,000
Total	32	388,000

Cycloversion

	No. Units	Approx. B/D Gas Oil Charge
Phillips Petroleum Company	1	12,000
OVERALL TOTAL	88	1,043,000

If pre-war trends in consumption of distillate and residual fuel oils are any indication of the post-war forecast in demand for these products, then it might be deduced that there will be a slowly increasing demand for distillate heating oils and diesel fuel and probably a dropping off in the demand for residual fuel oil. The extensive application of catalytic cracking particularly to heavy stocks which heretofore have been discarded as residual fuel oil components will in effect bring about a direct conversion of residual fuel oils into high octane motor gasoline and to a lesser extent, into domestic heating oils. It is predicted that there will be an increasing trend in the use of suitable boiling range catalytic distillates for domestic heating oils, for, during the war years, there has been a very sharp upturn in this direction in order to make available a maximum amount of light virgin charge stocks for catalytic cracking to produce aviation gasoline and other war products. While opinion among refiners regarding the use of large concentrations of catalytic distillates in home heating oils has been divided, it was initiated before the war and has been widely practiced during the war years with satisfactory marketing experience. The application of such processes as coking and propane deasphalting will further serve to reduce production of residual fuel oil and increase motor gasoline and No. 2 heating oil output through the medium of catalytic cracking. The selection of these latter processes will obviously depend upon marketability of coke, asphalt and residual fuel oil. In general, there will be an increasing trend toward the shift from viscosity breaking to the high gasoline yield producing combinations of catalytic cracking and propane deasphalting or coking. In situations where vacuum reduction facilities are available this may be applied in place of the propane deasphalting or coking.

In appraising any long range post-war marketing situation, refiners must not fail to give consideration to the possibility of voluntary and legislative action to conserve the national resource of petroleum. Such action might take the form of curtailed domestic crude runs with increased runs of foreign crudes, but might be more likely to assume a less direct form such as curtailment of domestic heating oil consumption through consumer taxation or otherwise. Motor gasoline forms such an important part of American economy that it is doubtful if there will be any important attempt made to reduce its consumption. The trend toward light high compression engines and light weight cars will be encouraged through maintenance of existing tax rates equal on all grades of gasoline with a definite reduction in consumer requirement and a probable coincident reduction in crude processing requirement.

Catalytic cracking plant performance is characterized by the production of relatively large quantities of butane-butylene fraction. While this is an invaluable war commodity, the pro-

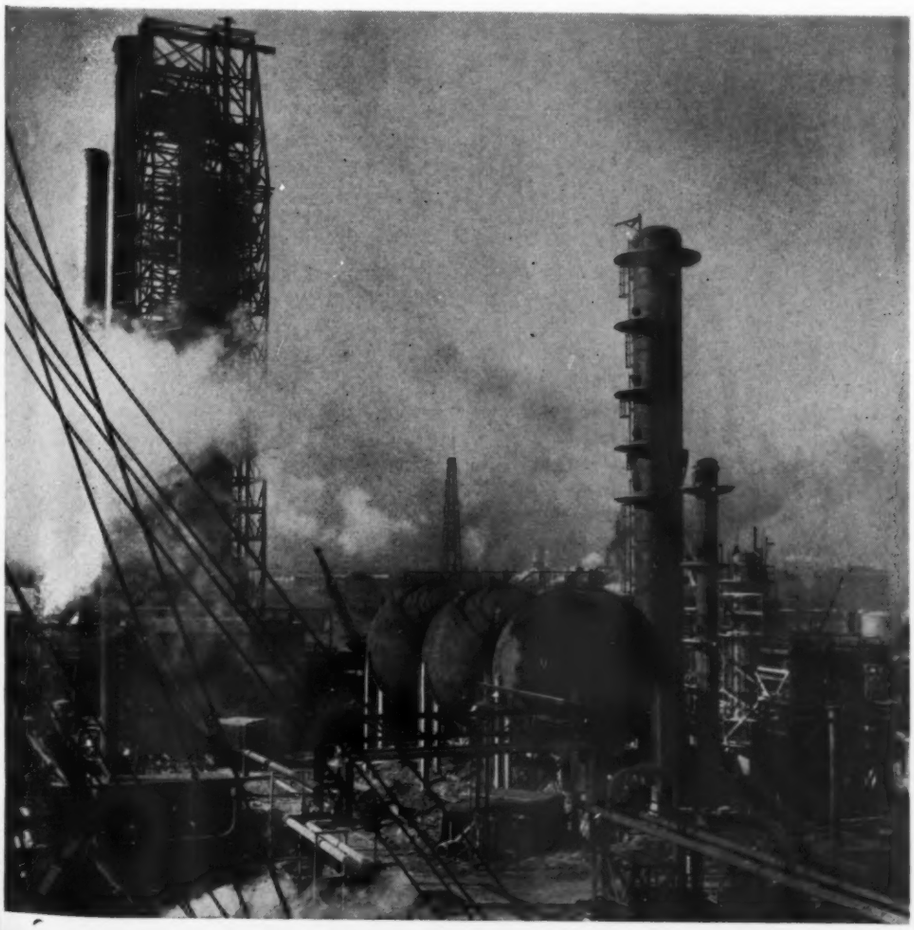
cessing of this material for motor gasoline production will necessitate the consideration of other processing systems than are being used during these war years. Furthermore, the use of butanes for bottle gas and automotive fuel, curtailed during the war years, will be again resumed probably on an increasing scale. In the final analysis butanes are too valuable to be discarded to fuel gas as had been done extensively in many refineries before the war. While the alkylation of pentenes and propylene will no doubt be discontinued in favor of direct inclusion of pentenes in motor gasoline and catalytic polymerization of propylene, the operation of existing alkylation plants for the production of butylene alkylate will continue and will afford many refiners a means of bringing his operation into vapor pressure balance. While the butylene alkylate will be used preferentially in aviation gasoline, its use in premium and super fuels will undoubtedly prove economically sound, especially as octane ceilings are elevated. The naphtha polyform process has been applied extensively for converting naphtha, butanes and propanes into high octane motor gasoline. This process employs temperature and pressure conditions that are quite suitable for the economical processing of refinery excess butanes. The application of this process is demonstrated in some illustrative studies presented later. In situations where reforming capacity is already available, catalytic polymerization may be effectively used to convert butylene and propylene into polymer gasoline and aid in establishing refinery vapor pressure balance.

In lubricating oil production the percentage of solvent refined oils was gradually increased from the early 30's up to the outbreak of the war. During the war years these newer facilities were utilized largely for the production of high grade aviation lubes. The war requirement for lube oils was supplied with the addition of very few new solvent plants. It is expected, therefore, that there will be considerable new construction of solvent refining plants for lube oils in the post-war period. The requirements for higher grade lubricating oils evidenced in the pre-war years are expected to be further increased. With the rising use of higher speed engines and higher speed industrial machinery, this effect will be accentuated. This extended use of solvent refined oils has been accompanied by the development and expanded use of many more additives. Refiners will modernize their lubricating oil blending and compounding plants so as to facilitate continuous and accurate blending of the various stocks and additives to finished grade. With more and more emphasis on the conservation of crude and with a forecast for increased lubricating oil requirements, the refiner is expected to obtain the ultimate recovery of lubricating oils from his crudes. In this connection he must give consideration to balancing his production of low and high viscosity components to meet the relative market requirements for the finished grades.

The war years witnessed an increase in the production of waxes with the development of many new uses of this material. The application of these new uses will no doubt be extended in the post-war period. The manufacture of micro-crystalline waxes has been shifting during the past decade from the centrifuge method to the use of solvent dewaxing. This has resulted in a higher quality product with increased melting point, thereby expanding the field of application of this product. The crystalline waxes have been shifting to a lesser extent from the press-sweating method to the solvent dewaxing process. While solvent dewaxing affords an improvement in quality in many cases the retirement of existing presses and sweaters cannot be completely justified. It is anticipated, however, that the facilities which will be provided in the post-war period for increased wax production requirements will be almost entirely solvent dewaxing plants. This type of equipment offers the flexibility of producing either the micro-crystalline or the crystalline waxes with the same plant at lower manufacturing costs, and with lower investment for new facilities. The refiner is also in a position to vary his operation in accordance with the market requirement for these two products, which is not possible with the old processing methods. There are still further advantages in production costs in the manufacture of both of these products to be realized by the simultaneous manufacture of low pour lubricating oils and waxes. This may be accomplished either by repulping continuously the wax cake from the pour production operation or by a two-stage operation. In the first stage specified melting-point wax is produced and the oil then passes continuously through the second dewaxing step for the production of required pour lubricating oil and slop wax. Some existing solvent dewaxing plants now operate with blocked operation producing pour oils and slack wax for one period of time and then recharge the slack wax back through the plant for the production of specified melting-point crystalline and microcrystalline waxes the balance of the time.

With the processing of more marginal crudes as well as foreign crudes, the question of sulphur removal from petroleum products becomes of greater importance to the refiner. Satisfactory methods are available for treating straight run gasoline and naphthas and to a lesser extent cracked gasoline. Existing methods are considered expensive both in investment and operating costs for the removal of sulphur from kerosenes. No commercial process is available today for the removal of sulphur from gas oils and reduced crudes. Considerable work is under way towards the development of processes which will satisfactorily and economically remove sulphur from kerosenes, gas oils and reduced crudes. It is anticipated that the post-war period will witness the commercial application of this much required processing step. Some of these requirements are minimized by the reduction of sulphur in gasoline made from the catalytic cracking of high sulphur gas oils, and propane deasphalted reduced crudes.

While a few refineries are at the present time engaged in fairly extensive manufacture of chemicals from petroleum raw materials, this field is yet in its infancy. The war accelerated this in-



TCC Unit (Left) and Alkylation (Right) in Large Butadiene Plant.

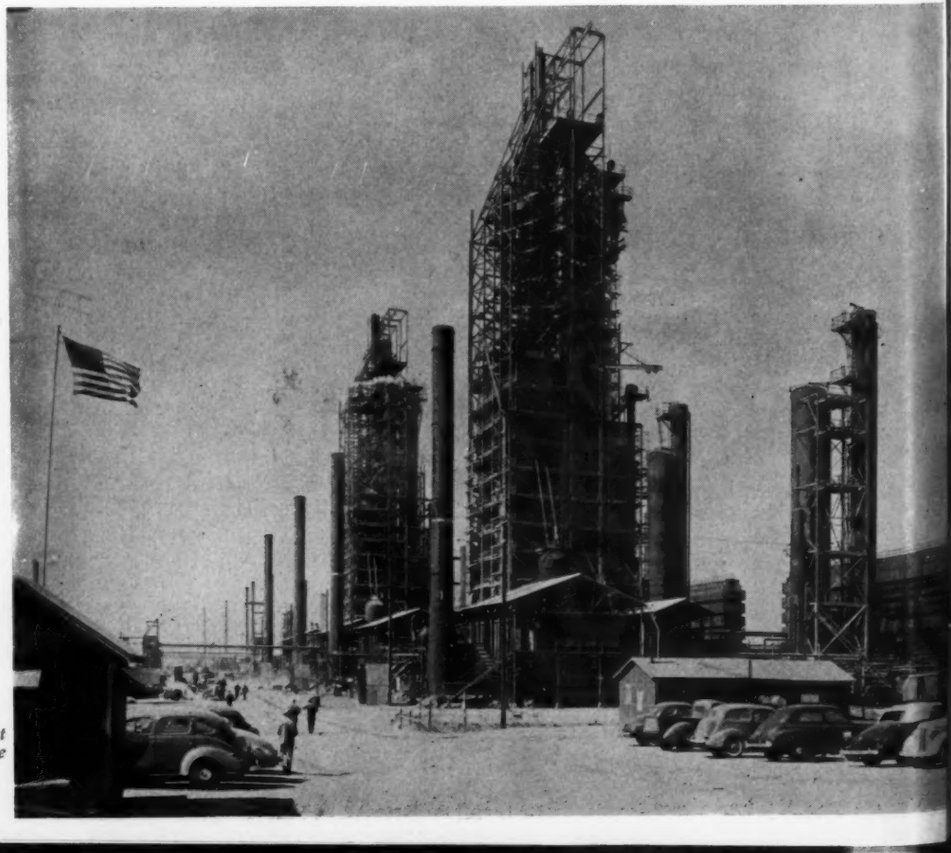
dustry by the greatly increased requirements for such materials as butadiene and styrene. The petroleum industry is such an important source of raw materials for the manufacturer of chemicals that it can no longer be overlooked by the chemical industry. Already there are a number of chemical firms which have located plants adjacent to oil refineries and have established chemical manufacture from petroleum raw materials. Several new companies have already been formed to engage in this field. The manufacture of ethylene, propylene, acetylene, and a great number of closely related chemicals is illustrative of this development. At the present time such operations are of very secondary nature to petroleum refineries; however, as the volume of this industry expands it will take on ever increasing importance.

In an attempt to further assist the refiner in planning his post-war operations, some general studies are presented herewith. As stated previously, it is necessary, before any studies can be made, to develop as accurately as possible market forecasts of the quality and quantity of all products. Having made this forecast, then it is possible to develop a series of overall refinery studies varying in each the capacity of the new processing units contemplated. For example, there are outlined in Table I three plans based upon the processing of 25,000 barrels per day of Mid-Continent crude. In each of these plans there is projected an atmospheric topping operation for the production of light straight run gasoline, heavy naphtha, kerosene, No. 1 fuel oil, diesel, No. 2 fuel oil and topped crude. The topped crude is charged first to a TCC cracking unit feed preparation system, where the reactor charge is flashed from the reduced crude. The heavy reduced crude remaining is then charged to a thermal cracking unit. In these studies the charge to the catalytic cracking plant has been established at 3000, 6000 and 9000 barrels per day with the thermal cracking capacity varying correspondingly. The severity of the catalytic cracking operation has been maintained the same for the three cases, notwithstanding the changes in the boiling range and gravity of the feed stock, by adjusting operating conditions. Minor adjustments have been made in product distribution. A naphtha polyform operation with 4000 barrels per day of heavy naphtha charge has been projected for each of these schemes. The charge to the polyform unit also includes 90 percent of the excess butane-butylenes from the thermal and catalytic cracking operations and 60 percent of the propane-propylene production from these operations. In this manner the plant is maintained in vapor pressure balance and conveniently recoverable propane-propylene is processed. The overall commodity balance for these three cases indicates a slight gain in gasoline production as the amount of catalytic capacity is increased and a gain in overall gasoline octane number of approximately 1.0 point for each 3000 barrels per day increment of catalytic cracking unit charge. For the purpose of comparison a fourth case in-

TABLE I

REFINERY BALANCES WITH VARYING TCC UNIT CAPACITIES

	Vol. %	Bbl./Day	Vol. %	Bbl./Day	Vol. %	Bbl./Day	Vol. %	Bbl./Day
Atmospheric Topping								
M. C. Crude Charge	100.0	25,000	100.0	25,000	100.0	25,000	100.0	25,000
Lt. St. Run Gasoline	15.0	3,750	15.0	3,750	15.0	3,750	15.00	3,750
Heavy Naphtha	16.0	4,000	16.0	4,000	16.0	4,000	16.0	4,000
Kero. + No. 1 Fuel Oil	5.0	1,250	5.0	1,250	5.0	1,250	5.0	1,250
Diesel + No. 2 Fuel Oil	10.0	2,500	10.0	2,500	10.0	2,500	10.0	2,500
Topped Crude	53.0	13,250	53.0	13,250	53.0	13,250	53.0	13,250
Loss	1.0	250	1.0	250	1.0	250	1.0	250
TCC Cracking								
Topped Crude to Flash Tower	.....	.....	53.0	13,250	53.0	13,250	53.0	13,250
Reduced Crude Bottoms	.....	.....	41.0	10,250	29.0	7,250	17.0	4,250
Flash Tower Overhead	.....	.....	100.0	3,000	100.0	6,000	100.0	9,000
10# R. V. P. Gasoline	.....	.....	48.0	1,440	48.0	2,880	48.0	4,320
Light Catalytic Cycle	.....	.....	25.0	750	25.0	1,500	25.0	2,250
Heavy Catalitic Cycle	.....	.....	16.0	480	16.0	960	16.0	1,440
Excess Butanes	.....	.....	6.0	180	5.5	330	5.0	450
Excess Butylenes	.....	.....	3.0	90	3.5	210	4.0	360
Propane	.....	.....	4.0	120	4.0	238	4.0	360
Propylene	.....	.....	3.4	102	3.4	204	3.4	306
Dry Gas F. O. E. Basis	.....	.....	3.0	90	3.0	183	3.0	270
Total	.....	.....	108.4	3,252	108.4	6,505	108.4	9,756
Thermal Cracking								
Reduced Crude Charge	100.0	13,250	95.5	10,250	85.7	7,250	63.6	4,250
Light Catalytic Cycle	.....	.....	.....	.....	3.0	250	14.9	1,000
Heavy Catalytic Cycle	.....	.....	4.5	480	11.5	960	21.5	1,440
Total	100.0	13,250	100.0	10,730	100.0	8,460	100.0	6,690
10# R. V. P. Gasoline	44.5	5,900	46.6	5,000	42.8	3,622	33.6	2,250
Heating Oil Withdrawn	9.4	1,250	4.6	500	.....	.....	.....	.....
No. 6 Fuel Oil	38.4	5,090	39.6	4,250	50.5	4,275	62.3	4,170
Excess Butanes	2.4	318	2.6	278	2.2	185	1.8	120
Excess Butylenes	1.1	146	1.2	130	1.1	92	.8	55
Propane	3.8	503	4.3	460	3.1	264	2.2	147
Propylene	1.9	251	2.1	225	1.5	130	1.0	67
Dry Gas F. O. E. Basis	3.6	475	3.5	375	3.0	250	2.0	135
Total	105.1	13,933	104.5	11,218	104.2	8,818	103.7	6,944
Polyforming								
Heavy Naphtha Charge	100.0	4,000	100.0	4,000	100.0	4,000	100.0	4,000
Butanes from TCC & Thermal (90% Rec.)	7.2	286	10.3	413	11.3	460	12.8	513
Butylenes from TCC & Thermal (90% Rec.)	3.2	130	5.0	200	6.8	270	9.3	373
Propane from TCC & Thermal (60% Rec.)	7.5	301	8.8	350	7.5	300	7.6	305
Propylene from TCC & Thermal (60% Rec.)	3.8	151	4.7	189	5.0	200	5.4	217
Total Charge to Polyform	121.7	4,868	128.8	5,152	130.8	5,230	135.1	5,408
10# R. V. P. Gasoline	81.6	2,264	84.6	3,385	85.3	3,411	88.2	3,533
No. 6 Fuel Oil	4.9	199	5.2	210	5.2	210	5.4	216
Dry Gas F. O. E.	28.0	1,120	29.5	1,180	32.0	1,280	30.0	1,200
Total	114.5	4,583	119.3	4,775	122.5	4,901	123.6	4,949
Overall Commodity Balance								
M. C. Crude Charge	100.0	25,000	100.0	25,000	100.0	25,000	100.0	25,000
10# R. V. P. Motor Gasoline	51.6	12,914	54.3	13,575	55.7	13,663	55.3	13,853
Kero. + No. 1 Fuel Oil	5.0	1,250	5.0	1,250	5.0	1,250	5.0	1,250
Diesel + No. 2 Fuel Oil	15.0	3,750	15.0	3,750	15.0	3,750	15.0	3,750
No. 6 Fuel Oil	21.2	5,289	17.8	4,460	17.9	4,485	17.6	4,386
Dry Gas F. O. E.	7.3	1,821	7.8	1,942	8.0	2,005	7.7	1,921
Total	100.1	25,024	99.9	24,977	100.6	25,153	100.6	25,160
Motor Gasoline Octane Numbers								
Production, BPCD		12,914		13,575		13,663		13,853
Clear MM		68.5		70.0		71.0		72.0
MM + 3 cc		80.5		82.0		83.0		84.0



Two Large TCC Units on West Coast in Aviation Gasoline Plant.

corporating thermal cracking but omitting catalytic cracking is included. In this study the motor gasoline production is about 650-950 barrels per day less than in the studies including the TCC units and the octane number of this motor gasoline is approximately 1.5 points lower than for the study in which 3000 barrels per day of catalytic cracking capacity was included. In each of these four studies the production of virgin distillate fuels was maintained at 15 percent of the crude charge and the production of cracked distillate fuel was maintained at 5 percent of the crude charge, making a total distillate fuel production of 20 percent. These studies could be further extended by the installation of a vacuum reduction or propane deasphalting step to increase the catalytic unit charge to a maximum of approximately 12,000 barrels per day. With an estimate of the future motor gasoline octane number and production requirement, it is then possible to develop economic studies and assign relative profitabilities to each of these cases and determine which installation represents the optimum return on the investment for any given amortization period.

In Table II there is projected a similar series of studies in which the catalytic cracking and thermal cracking capacities have been maintained constant but the naphtha polyforming capacity has been established at 2000, 4000 and 6000 barrels per day. The overall commodity balances for these three studies indicate motor gasoline production descending from 14,200 barrels per day for the 2000 barrel case down to 13,250 barrels per day for the 6000 barrel case. Coincident with this decrease in motor gasoline production is an increase in motor gasoline octane number ranging from 67 to 73 clear, and 79 to 84 with 3 cc. of tetraethyl lead addition. It appears that there is an attractive gain in octane number resulting from increasing the polyform capacity from 2000 to 4000 barrels per day but somewhat smaller gain for the next 2000 barrel increase. As in the first series of studies, operating costs and commodity values can be assigned in the various cases and relative profitabilities can be determined on the basis of the future marketing requirements to determine the most profitable operation for a given amortization period.

While these studies illustrate one approach to the problem of post-war planning, especially for the small refinery, they are not intended to lead to any generalization pointing to the optimum catalytic cracking or reforming capacity for this particular situation. This presentation is made more to illustrate the necessity for developing a series of overall refinery processing schemes in order to be assured of an accurate appraisal of any projected refining and marketing situation. The authors of this paper will welcome the opportunity to develop in all of the necessary detail an analysis of future marketing conditions, and a study of refinery processing schemes which will assist any refiner in making the best selection of process equipment and in establishing the most profitable operations to meet his particular requirement.

TABLE II

REFINERY BALANCES WITH VARYING POLYFORM UNIT CAPACITIES

	6000 TCC 2000 Poly		6000 TCC 4000 Poly		6000TCC 6000 Poly	
	Vol. %	Bbl./Day	Vol. %	Bbl./Day	Vol. %	Bbl./Day
Atmospheric Topping						
M. C. Crude Charge	100.0	25,000	100.0	25,000	100.0	25,000
Lt. Str. Run Gasoline	23.0	5,750	15.0	3,750	7.0	1,750
Heavy Naphtha	8.0	2,000	16.0	4,000	24.0	6,000
Kerosene + No. 1 Fuel Oil	5.0	1,250	5.0	1,250	5.0	1,250
Diesel + No. 2 Fuel Oil	10.0	2,500	10.0	2,500	10.0	2,500
Topped Crude	53.0	13,250	53.0	13,250	53.0	13,250
Loss	1.0	250	1.0	250	1.0	250
Total	100.0	25,000	100.0	25,000	100.0	25,000
TCC Cracking						
Topped Crude to Flash Tower	53.0	13,250	53.0	13,250	53.0	13,250
Reduced Crude Bottoms	29.0	7,250	29.0	7,250	29.0	7,250
Flash Tower Overhead	100.0	6,000	100.0	6,000	100.0	6,000
10# RVP Motor Gasoline	48.0	2,880	48.0	2,880	48.0	2,880
Light Catalytic Cycle	25.0	1,500	25.0	1,500	25.0	1,500
Heavy Catalytic Cycle	16.0	960	16.0	960	16.0	960
Excess Butanes	5.5	330	5.5	330	5.5	330
Excess Butylenes	3.5	210	3.5	210	3.5	210
Propane	4.0	238	4.0	238	4.0	238
Propylene	3.4	204	3.4	204	3.4	204
Dry Gas (FOE Basis)	3.0	183	3.0	183	3.0	183
Total	108.4	6,505	108.4	6,505	108.4	6,505
Thermal Cracking						
Reduced Crude Charge	85.7	7,250	85.7	7,250	85.7	7,250
Light Catalytic Cycle	3.0	250	3.0	250	3.0	250
Heavy Catalytic Cycle	11.3	960	11.3	960	11.3	960
Total	100.0	8,460	100.0	8,460	100.0	8,460
10# RVP Motor Gasoline	42.8	3,622	42.8	3,622	42.8	3,622
No. 6 Fuel Oil	50.5	4,275	50.5	4,275	50.5	4,275
Excess Butanes	2.2	185	2.2	185	2.2	185
Excess Butylenes	1.1	92	1.1	92	1.1	92
Propane	3.1	264	3.1	264	3.1	264
Propylene	1.5	130	1.5	130	1.5	130
Dry Gas (FOE Basis)	3.0	250	3.0	250	3.0	250
Total	104.2	8,818	104.2	8,818	104.2	8,818
Polyforming						
Heavy Naphtha Charge	100.0	2,000	100.0	4,000	100.0	6,000
Butanes (90% Rec.)	23.0	460	11.5	460	7.7	460
Butylenes (90% Rec.)	13.5	270	6.8	270	4.5	270
Propane (60% Rec.)	15.0	300	7.5	300	5.0	300
Propylene (60% Rec.)	10.0	200	5.0	200	3.3	200
Total	161.5	3,230	130.8	5,230	120.5	7,230
10# RVP Motor Gasoline	97.5	1,951	85.2	3,411	83.4	5,000
No. 6 Fuel Oil	6.4	129	5.3	210	4.8	289
Dry Gas (FOE Basis)	37.1	743	32.0	1,280	27.8	1,669
Total	141.0	2,823	122.5	4,901	116.0	6,958
Overall Commodity Balance						
M. C. Crude Charge	100.0	25,000	100.0	25,000	100.0	25,000
10# RVP Motor Gasoline	56.8	14,203	54.7	13,663	53.0	13,252
Kerosene and No. 1 Fuel Oil	5.0	1,250	5.0	1,250	5.0	1,250
Diesel and No. 2 Fuel Oil	15.0	3,750	15.0	3,750	15.0	3,750
No. 6 Fuel Oil	17.6	4,404	17.9	4,485	18.2	4,564
Dry Gas (FOE Basis)	5.9	1,468	8.0	2,005	9.6	2,394
Total	100.3	25,075	100.6	25,153	100.8	25,210
Motor Gasoline Octane Numbers						
Production, BPCD		14,203		13,663		13,252
Clear MM		67.0		71.0		73.0
MM + 3 cc.		79.0		83.0		84.5

One of the Control Rooms of the Neches Butadiene Plant.

New Oil Prevents Fingerprint Rust

RUST, caused by fingerprints on delicate instruments of war, is being prevented as the result of a special oil developed by the Socony-Vacuum Oil Company, Inc. Described by supply officers as an "enemy on the home front," rust on instruments with tolerances in fractions of thousandths of inches, ball bearings, aviation motor parts and superchargers may result in the failure of those parts to function properly. The chemical reaction of fingerprints as a result of frequent handling is a cause of such rust.

As a preventive Socony-Vacuum scientists have developed an oil that has the appearance of heavy kerosene and is red in color. Dipping metal and steel parts in this oil at various stages on the production line not only gets rid of fingerprints at that time but also makes the part "immune" to fingerprints for several months afterward.

Army Pilot Joins Briggs Company

A. M. ANDREWS, veteran pilot of many war theatres, has joined the staff of the Briggs Clarifier Company as one of the chief service engineers for the Aviation Division. Entering the Ferry Command as a civilian pilot soon after Pearl Harbor, Mr. Andrews was shortly afterwards commissioned 2nd Lieutenant in the Army Air Forces. Before his discharge as a Captain in 1944, he had to his credit five Atlantic crossings as well as 84 missions "over the hump" while in the China-Burma-India theatre.

The Briggs Company is engaged in manufacturing oil maintenance equipment for the Army, Navy, Coast Guard and Maritime Commission.

Educational Leave for Texaco Employes

A special leave of absence will be granted to employes of The Texas Company who return from military service and who desire to take advantage of the Servicemen's Readjustment Act of 1944 (the G. I. Bill) to pursue studies that will benefit them in their future association with the company, it is announced by W. S. S. Rodgers, chairman of the Board of Directors. In addition, financial assistance in the form of loans without interest will be extended to these veterans in cases where the amount available under the law may be inadequate.

The leave is for one year, subject to extension at the end of each year, provided the employe is making satisfactory progress in his studies. The educational leave is available to any employe who had at least four months' service with Texaco before entering the military service. Upon the employe's return to company service, full consideration will be given to the knowledge and skill acquired while on education leave and to his accumulated seniority with the company, including the period of his leave. More than 5,000 men and women of The Texas Company are on military leave of absence.

Peru's Oil Production

PRODUCTION of oil in Peru has been substantially increased during the war period in response to urgent demands for petroleum products for use in military operations in the Pacific and to relieve shortages due to the diversion of shipping from customary routes. Statistics of output for the past two years are now available and are as follows in barrels of 42 gallons:

	1943	1944
Crude Oil	14,654,498	14,385,926
Natural Gasoline	1,046,891	1,033,768
Total	15,701,389	15,419,694

The above figures for 1943 are from official records published in the "Anuario de la Industria Minera en el Peru" while those for 1944 are estimates from private sources which are accepted as approximately correct.

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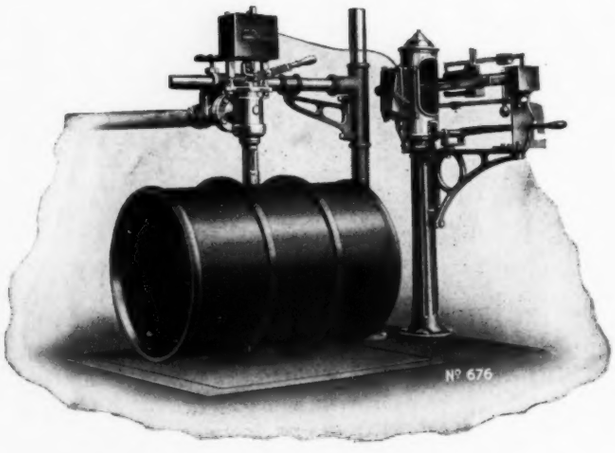

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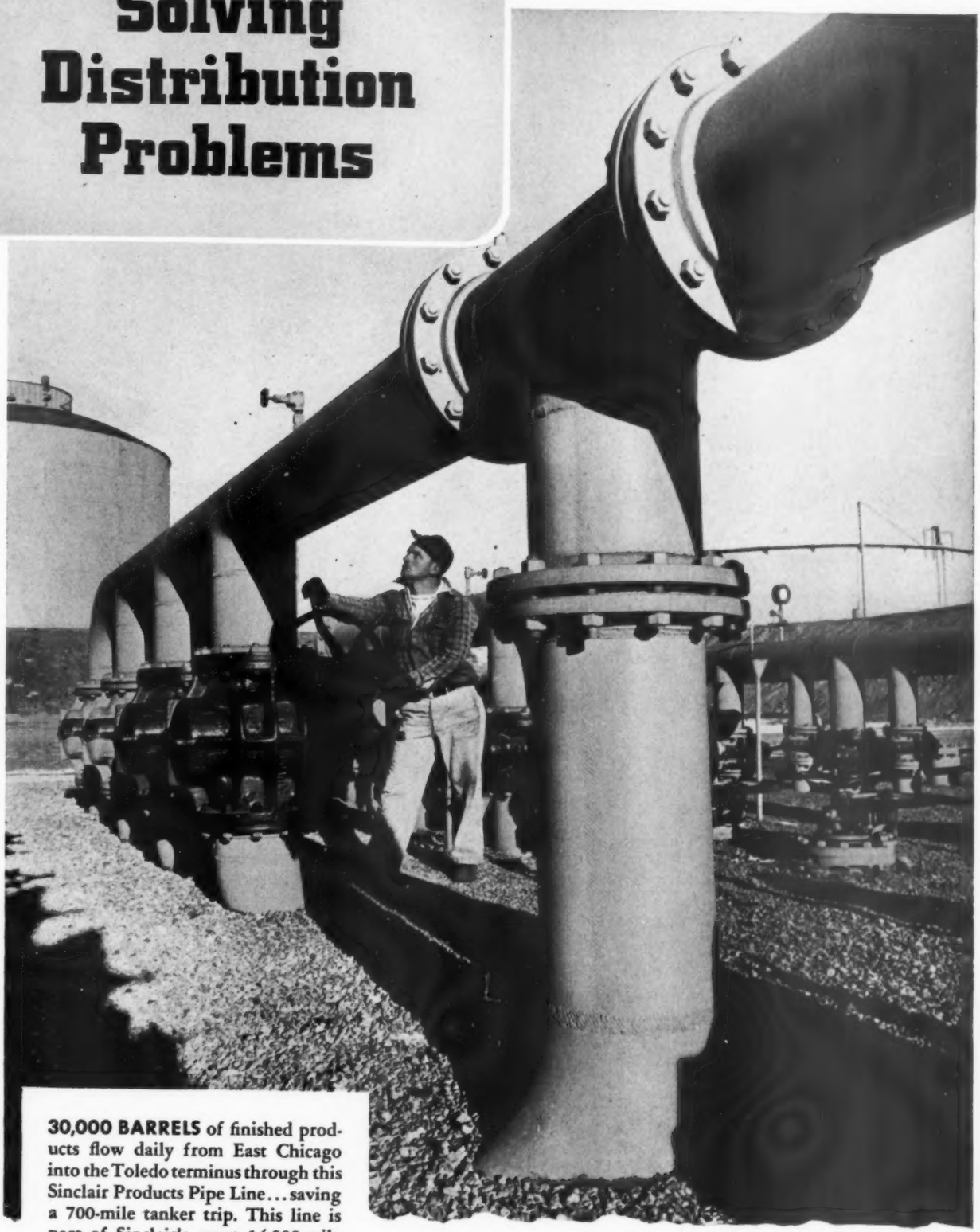
BOLTON, ENG.

Solving Distribution Problems



30,000 BARRELS of finished products flow daily from East Chicago into the Toledo terminus through this Sinclair Products Pipe Line... saving a 700-mile tanker trip. This line is part of Sinclair's great 14,000-mile crude oil and products pipe line system which helps in solving the petroleum industry's transportation and distribution problems.

Sinclair Refining Company

SINCLAIR

(*Continued from page* 104)
holding out for 5 cents; some would take three or four, and be glad to get it. It may thus be said that the synthol process is especially aimed at tapping a great source of raw material that is now unusable by reason of geographic and economic circumstances.

As regards the technology of the Fischer-Tropsch synthesis applied to natural gas, the engineering firms that offer licenses to operate their processes have not informed the general public about the details of these processes. However, enough is now known about the Fischer-Tropsch synthesis and recorded in technical publications here and abroad to show the lines along which the newly offered versions of the process must have been evolved.

A brief review of the history of the Fischer-Tropsch synthesis will here be in order. About 1913 a German chemical concern evolved a process of mixing the two gases, carbon monoxide and hydrogen, and subjecting this mixture to high temperature and pressure in the presence of a catalyst impregnated with an alkali. The product of the operation was a mixture of saturated and unsaturated gaseous and liquid hydrocarbons, alcohols, acids and ketones.

In 1923 the German research team of F. Fischer and H. Tropsch repeated this operation, also at high temperature and high pressure, but making use of an alkali-iron catalyst. The product now was a mixture of organic chemicals such as aliphatic alcohols, aldehydes, ketones, acids and esters. To this product Fischer and Tropsch gave the name of Synthol (synthetic oil), although it contained no hydrocarbons. By subjecting synthol to a subsequent heating, it was converted into a mixture of hydrocarbons which they called kogasin (coal-gas kerosine). In pursuing their studies, Fischer and Tropsch found that by increasing the amount of alkali in the catalyst the proportion of organic chemicals was increased, thus increasing the production of synthol; on reversing the conditions by using low pressure, a high ratio of hydrogen to carbon monoxide in the gaseous mixture, and leaving alkali out of the catalyst, they obtained a product consisting almost entirely of hydrocarbons.

The proposition then became one of finding the kind of catalyst and the right temperatures and pressures that would give the maximum yield of the most desirable hydrocarbons. After a while it was found that the best catalyst for the synthesis of kogasin was cobalt, thoria, and kieselguhr in the proportions of 11, 80 and 100, respectively. This catalyst is most active at temperatures between 375 and 390°F. In 1933, the year Hitler came into power in Germany, the kogasin process had developed to the point where Germany could make at least an approach to national self-sufficiency in petroleum products. By 1936 the process had been improved so that about 9.5 lbs. of liquid petroleum products could be obtained from 1000 cu. ft. of a mixture of carbon monoxide and hydrogen. One disadvantage remained. The original Fischer-Tropsch is largely a mixture of straight-chain hydro-carbons with small proportions of aromatics and naphthenes. Because of the presence of straight-chain hydrocarbons in the primary reaction product the gasoline fraction of kogasin has a very low octane number, even in the fraction boiling up to 302°F. The octane number could, of course, be raised by subsequent additional steps of reforming and cracking by conventional processes.

The above particulars of the Fischer-Tropsch synthesis have long been common knowledge, but that further progress has been made is vaguely indicated in articles published by Fischer about the time World War II was getting underway. In his latest available publication Fischer speaks of phases of his process which he calls the "naphthene synthesis" and the "iso synthesis". By the "naphthene synthesis" it is implied that a particular catalyst or particular operating procedure has been found that will enrich the kogasin in aromatics and napthenes and thereby improve the octane rating of the gasoline fraction. By the "isosynthesis" it is further implied that a way has also been found to produce iso-paraffins which too would benefit the octane rating of the synthetic gasoline. In fact, Fischer says that the C_4 fraction obtained from the "isosynthesis" contains 90 percent of iso-butane. This is a significant development, because the Fischer-Tropsch synthesis is thus able to supply the basic materials (iso-butane and iso-butene) for 100-octane aviation gasoline. It also suggests a foundation for the claim of the Kellogg Company that its version of the Fischer-Tropsch synthesis can give an 80 percent yield of 75-octane gasoline which is then subject to a wide improvement by the use of tetraethyl lead. Evidently, the Kellogg catalyst is able to bring about the naphthene synthesis or the iso-synthesis, or perhaps both.

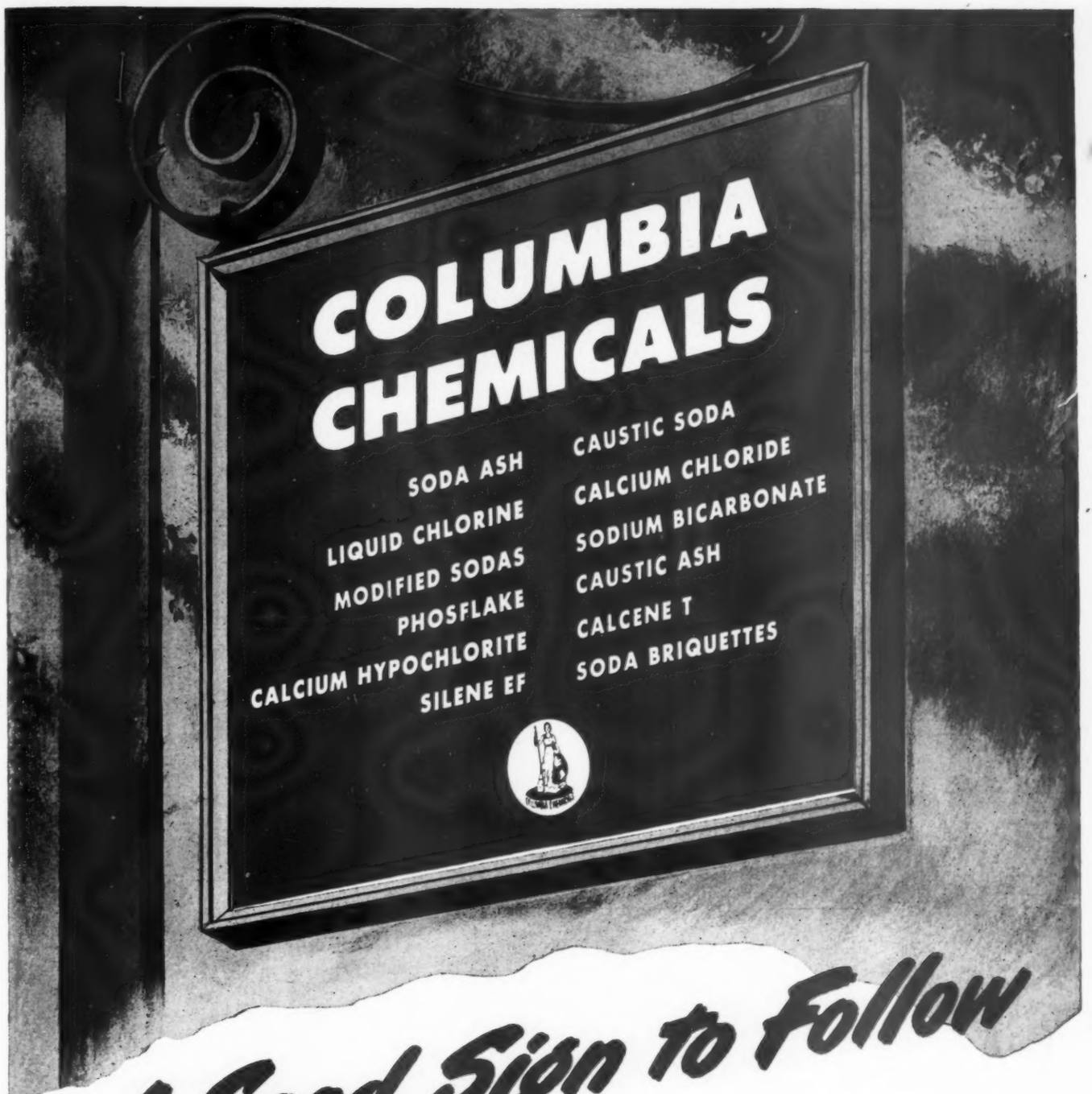
By gathering up the information which is now in the published record of the Fischer-Tropsch synthesis applied to the methane of natural gas from which the higher hydrocarbons have been more or less separated for direct use, we may obtain a fairly close idea of the technology of the modern versions of this synthesis.

The well-known water-gas reaction will be applied to the natural gas in a way that will result in the most favorable mixture of hydrogen and carbon monoxide. The carefully purified gas mixture (sulphur not more than 0.1 grain per 100 cu. ft.) is passed over a proper catalyst at a moderate pressure (75 to 225 psig). The catalyst chamber must be equipped with efficient means for absorbing the heat of reaction to prevent a rise of temperature that would favor the production of hydrocarbons that boil above the gasoline range. Very careful attention will be paid to the choice of catalyst. There are apparently a number of choices, but in any case the catalyst must be a mixed one, because, according to current theory of the Fischer-Tropsch synthesis, the catalytic conversion of CH_4 to higher hydrocarbons proceeds in two stages. First, the catalyst must contain a metal which forms a carbide with the carbon of the CH_4, setting free atomic hydrogen. Next the mixed catalyst must also contain a metal which acts as a hydrogenating catalyst that reduces the carbide to methylene groups, which polymerize to the desired C_3, C_4 and C_5 hydrocarbons. Cobalt is generally regarded as a suitable carbide-forming metal, while iron seems to be the preferred hydrogenating metal. There is some talk of adding a third metal that will promote the polymerization of methylene to the most desirable of all the gasoline hydrocarbons, namely, the iso-paraffins.

The Kellogg Company have distributed a generalized flow sheet of their process. This flow sheet indicates the main course of operations. First is the purification (sulphur removal) of the raw gas, which is then converted by the water gas reaction into a mixture of carbon monoxide ("synthesis gas"), which is then passed through the catalyst chamber and on through a condenser. Here liquid hydrocarbons are separated from gaseous products, and a separator removes water from the gas stream. In turn, the lighter hydrocarbons are separated from the residual gas, which may be used as fuel. The main part of the oily product is subjected to fractioning, yielding gasoline as the main product and with secondary amounts of diesel oil. Part of the C_3 and C_4 fractions may be polymerized to branched hydrocarbons and the product added to the gasoline.

This procedure is said to be susceptible of variation so as to produce "desired chemical compounds" which, as they are contained in the water separated from the crude product, may consist of oxygen compounds such as acids, aldehydes, alcohols, ketones, etc. The production of these chemicals is controlled by controlling the operating conditions, which may perhaps include the purposeful introduction of oxygen or extra carbon dioxide or possibly the use of alkali with the catalyst, which is known to favor the formation of organic oxygen compounds.

The Kellogg Company specifies what it considers "favorable conditions" for the success of its process. These specifications include a location near large gas reserves. Approximately 11,000 cu. ft. of natural gas are required to produce one bbl. of liquid hydrocarbon product. The plant should preferably be located on water to obtain the cheapest transportation cost for both the hydrocarbon and the chemical products. It is suggested that location on the Gulf Coast whence transportation would be available for shipment to the East Coast and the Upper Mississippi Valley, would be quite advantageous. The most favorable condition of all, however, is seen in the possibility of using the Fischer-Tropsch synthesis as a tool for bringing surplus reserves of natural gas into the market.



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WORLD PETROLEUM ABSTRACTS

Summaries of the Most Important Articles as Published in the Oil Press of the World Dealing with Technical and Economic Aspects of the Petroleum Industry—Edited by Dr. O. W. Willcox.

REFINING

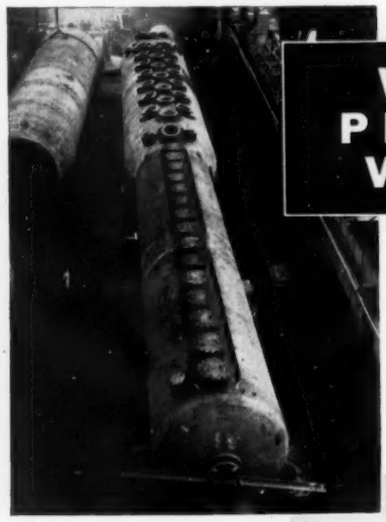
Glass Fibers as Packing for Distilling Columns—Geo. W. Minard, Joseph H. Koffalt and James R. Withrow, in TRANSACTIONS AMERICAN INSTITUTE CHEMICAL ENGINEERS, Vol. 39 (1943), pp. 813-857.

skilled manpower to construct new plate columns, Due to the fact that existing alcohol distillation units have been taxed to the utmost by war demands and inability to procure materials and some industrial alcohol plants have built columns with glass fibers as the packing materials.

(According to a statement issued by the Owens-Corning Fiber Glass Corporation, the columns at the Bardstown, (Ky.) plant of Hiram Walker & Sons are 43 feet and 7/8 inches high with inside diameter of 50 inches. There are four packed sections in each column, each 7 feet high. The glass fibers average 20 inches in length and 0.0085 inch in diameter, and are packed in these sections at a density of 3.7 lbs per cu. ft. Rate of feed to the columns is 11,200 gals. per hour and the amount of product taken per hour is 4,700 gallons. The reflux amounts to 2,300-2,400 gallons per hour and the velocity of vapor in the columns is 5 feet 6 inches per second. The alcohol obtained is from 190.0 to 191.4 proof, with the greater part of the production near the higher proof.)

To obtain precise data on the chemical engineering characteristics of this material the authors of this paper constructed and operated two laboratory columns packed with glass fibers at a density of about 4 lbs. per cu. ft. Runs were made on the systems ethanol-water and methanol-water at vapor velocities of 0.80 to 5 ft. per second. Within the ranges investigated rate of throughout had no appreciable effect on the performance characteristics of the packing. Pressure drops were exceedingly low at vapor velocities as high as 5 feet per second, and it appears that higher rates of throughput might be obtained.

The conclusion is that glass fiber packing appears to possess all the characteristics of a satisfactory material for packed column distillation work, including good rectifying performance, high rate of throughput with low pressure drop, consistent behavior under long use, light weight per unit volume, and low cost.



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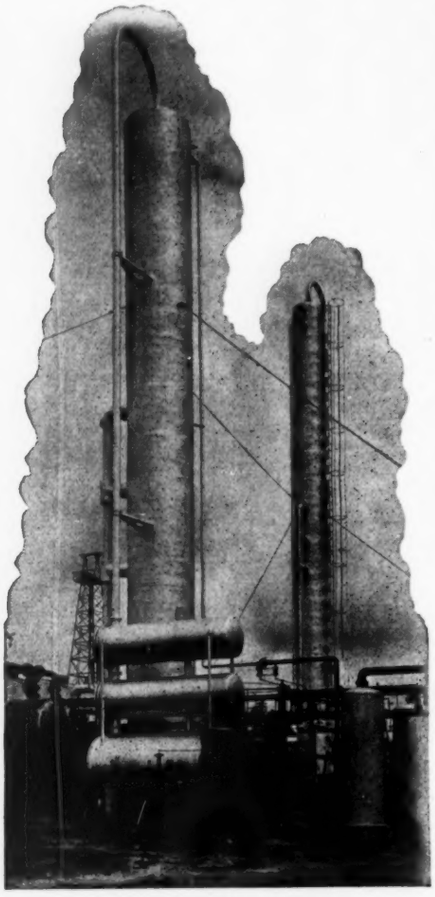
KENNEDY BLDG. • TULSA, OKLA.

Thermofor Catalytic Cracking.—H. S. Armstrong, before California Natural Gasoline Association, Los Angeles, September, 1944.

A simplified type of TCC units has been recently developed which places the catalytic cracking process within the reach of the smaller operator desiring to charge from 2000 to 6000 BPSD of gas oil. This modified type of TCC unit possesses a high degree of simplicity and therefore requires a minimum of operational expense, but nevetheless incorporates all of the flexibility of fundamental process variables that is characteristic of present commercial TCC units.

There appears to be a rapid trend towards the selection of relatively heavy stocks for catalytic processing to motor gasoline during the postwar period, prompted by the ever-increasing demand for virgin high cetene number diesel fuels and for home heating oils. Hence, in many instances catalytc cracking plant charge stocks will be relatively void of components boiling below 600° F. and will contain a maximum of the higher boiling components depending upon the limitations of the catalytic cracking process employed. The TCC process is especially well adapted to the processing of heavy gas oil charging stocks as a result of the exceptionally low coke production coincident with TCC operation. For example, TCC units are especially suited to the processing of 26 to 28° API gas oils, having mid-boiling points ranging from 700-800° F. and end points ranging up to 1050° F. Yields will approximate 50% 10# RVP motor gasoline with a motor method-clear octane of 80 and a research clear of 90. With 3cc of T. E. L. these become 86 to 88 and 95 to 96.5, respectively; 25 to 27% #2 furnace oil distillate will be produced and 15 to 17% heavy catalytic gas oil. These operations are characterized by high propane-free liquid recovery and high recovery of 10# RVP motor gasoline plus catalytic gas oil. This heating oil distillate possesses exceptionally good stability and compares favorably with virgin heating oils and with heating oils produced from the Houdry process.

The TCC process offers the possibility of utilizing substantially all crude distillate fractions for production of high-octane aviation-base stocks and useful by-products, with little or no auxiliary processing other than fractionation. In the manufacture of motor gasoline the same latitude in choice of stocks exists and, in addition, the output of motor gasolne from a given TCC Unt is much greater than that of aviation gasoline, due to the wider boiling range of the product and the elimination of the treating operations.



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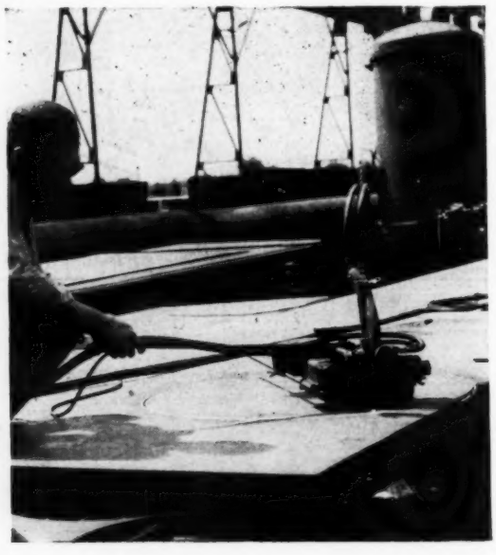

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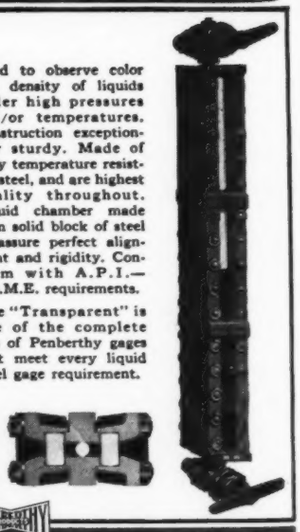

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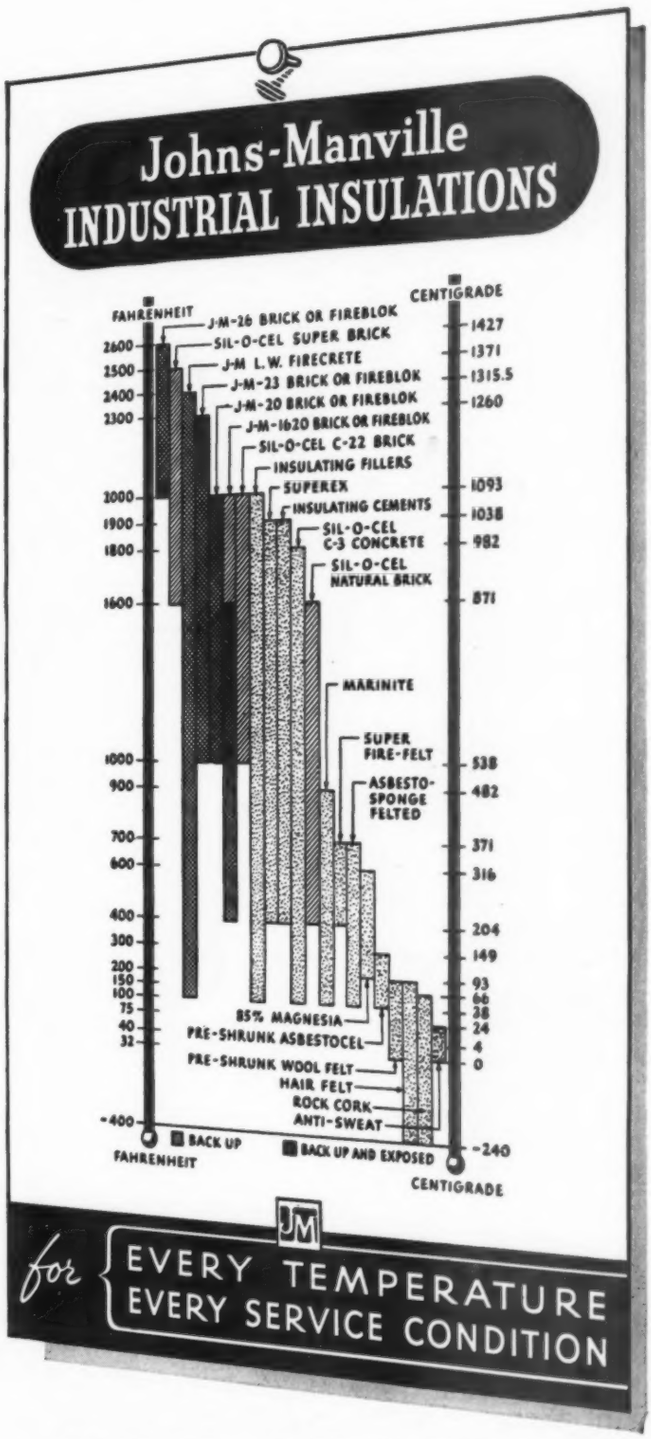

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INDUSTRIAL INSULATIONS
for every temperature—for every service

High-Efficiency Multitubular Packed Columns—E. H. Smoker, in Transactions American Institute Chemical Engineers, Vol. 40 (1944) p. 105.

For the purpose of fractionating large quantities of hydrocarbons having narrow boiling ranges, with the additional features of high efficiency, low liquid hold-up, and low pressure drop through the distilling apparatus, the author describes the construction and operating characteristics of a still commercial size which combines these essential features.

The column consists of five identical sections 30 inches in diameter, each containing seven 8-inch O.D. steel tubes in parallel. Funnels collect reflux from each tube of each section except the lowest and distribute it to the tube immediately below in the next section. Thus the reflux streams introduced into the top section are kept separate as they flow down the tubes, while the ascending vapors are free to mix in the open spaces between sections. The tubes are packed with 1-inch Berl saddles to identical heights (9.25 ft.), given an overall height of packing equal to 46.25 ft. and the total cross-sectional area 2.18 sq. ft., equivalent to a single column 20 inches in diameter.

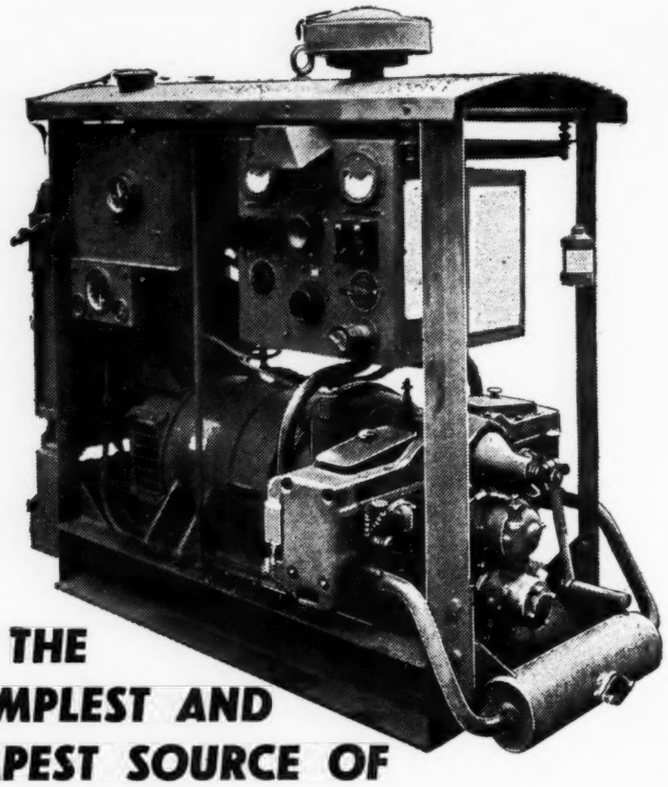
The pot consists of a storage tank containing no heating unit, of about 1500 gallons capacity, and a tray-type reboiler containg four trays, staggered to permit cascading flow from one tray to the next and finally to the storage tank. Each tray contains a single row of steam coils and permits a liquid depth of about 4 inches. A 500-gpm pump circulates charge stock from the base of the pot to the top reboiler tray. This permits vaporization at substantially the pressure at the base of the column and avoids overheating the charge resulting from hydrostatic head, which could readily be greater than column base pressure when high-vacuum distillations are carried out.

The reflux stream is subdivided into seven equal parts, one for each tube of the top section, by means of seven identical rotameters in parallel, the flow of each being controlled by a needle valve and the temperature adjusted by a reflux heater.

Operating Data on Column

	Atm. press.	200 mm. press.
Throughput (gal./hr./sq. ft.)	260	155
No. theoretical plates	51	46
Pressure drop (mm. mercury)	175	140
Hold-up (gals.)	35	35

Special features of the column included an automatic steam control to the reboiler, operated by



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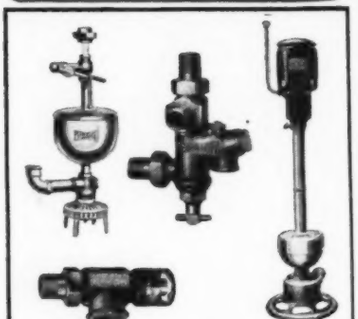

Penberthy injectors—ejectors—automatic electric and water (or steam) operated sump pumps are all widely used throughout the oil industry because they have always been dependable under the most severe service conditions.
All are of rugged construction and made by an organization with 59 years experience in the manufacture of highest quality products.

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uses hot oil or residuum to generate high-pressure steam

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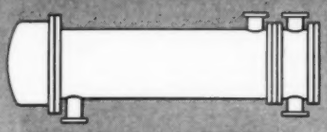

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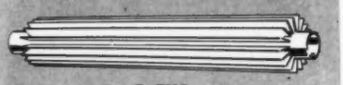
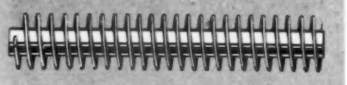
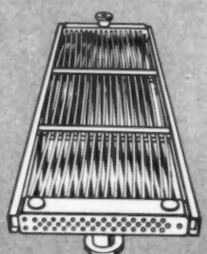
Heaters, Coolers, Condensers, Heat Exchangers



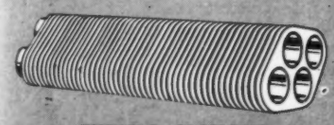
G-FIN
Longitudinal-finned elements for greater heat conductivity



K-FIN
Helical-finned elements for vapors and gases



BENTUBE SECTIONS
with scale-shedding elements for hard or salt water



TUBEFLO SECTIONS
Non-clogging design for residuum and other dirty fluids

If you are now cooling hot gas oil or cracking coil tar with water and if profitable heat exchange to process fluids is not possible, you should investigate the G-R Bentube Steam Generator.

This unit uses the heat in such high-temperature liquids to generate steam at boiler pressures from raw untreated water. **The resulting benefits** . . . recovery of waste heat . . . less load on your cooling system . . . lower pumping costs . . . reduced steam demand from the boiler house.

And note, too, these important features of design . . . scale-shedding heating elements that do not require manual descaling . . . countercurrent flow of water and hot liquid for maximum steam production . . . liquid passages can be made large and with uniform area throughout their length, so that continuous high velocity of the liquid can prevent clogging from tarry or dirty fluids.

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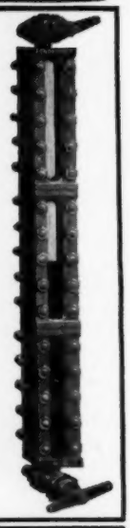
The "Reflex" is one of the complete line of Penberthy Gages that meet every liquid level gage requirement.



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means of the pressure drop across the column. In this way throughput and efficiency were kept at a high level, flooding was avoided, and the time elapsing between flats in the distillation range was reduced. An instrument was constructed to record the overhead temperature corresponding to an absolute pressure of 20 mm. regardless of what the absolute pressure actually was. This permitted cut points to be specified at 20 mm. pressure, the distillation to be continued at whatever pressure was desirable for the particular feed stock, without attention to the pressure fluctuations normally occuring.

Industry's Directive

(*Continued from page 69*)

be increased at a tempo far beyond any action in Europe, practically all of the tankers released from Atlantic service by the reduction of military requirements there will now be required in the Pacific.

The refining industry of the United States has done a magnificent job during this war, and I am glad to pay tribute to that fine record of performance. Despite all manner of difficulty, the refineries have met in full and on time the shifting war requirements. Men at the stills stayed at their posts despite fatigue and illness. The stillman changed the valves without complaint whenever the military shifted its requirements. Above all, the refining industry continued to serve, as much as it could, its civilian customers while, at the same time, it served the military—and it served both promptly and efficiently.

When the war against the Japs is over, the reconversion of the refining industry to the manufacture of peace-time products should pose no large problem because the same facilities that have been turning out war material will once again be employed in the manufacture of petroleum products for normal civilian consumption. The new refining equipment that has been constructed to supply 100 octane aviation gasoline, and the great advances in technology that have been stimulated by the war necessity, will make it possible for the industry to improve the quality of peace-time products—to the great benefit of the consuming public. It seems likely, also, that the industry will be able to employ its new facilities and technology in the production of a wide variety of synthetic products and raw materials for the manufacture of chemicals.

Over the past several years of war and preparation for war, the petroleum industry has "delivered the goods". It has established for itself an enviable record. The military order has been met in full, the wheels of industry have been kept turning without interruption, and the essential civilian requirement has been met. But the success that has been attained thus far must not blind us to the heavy responsibilities that still lie ahead. The military requirement for petroleum has not diminished with the end of the European war, but has increased. We shall have all that we can do to make both ends meet over the period ahead. All petroeum facilities, world-wide, must be operated on an all-out basis, as we have no margin to spare.

I have complete confidence in the petroleum industry, and I know that, as the war draws toward the end, there will be no tendency to let up, but only a renewed determination to devote every resource and every facility to the war purpose until final victory is achieved.

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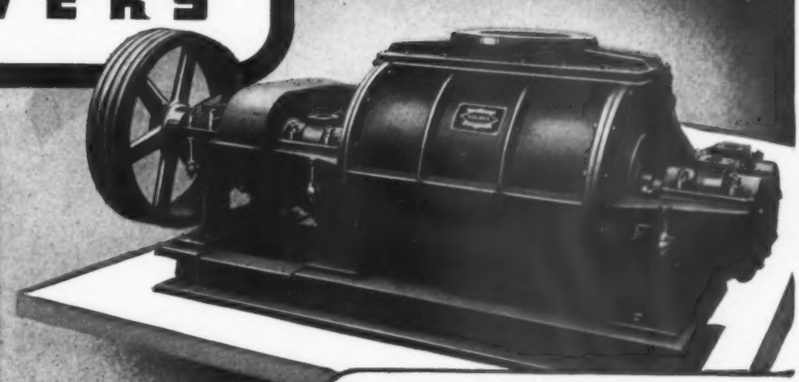

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Mexico's Refining Program Making Good Progress

DETERMINED to bring all Mexico's refineries to first class status with a view to the better servicing the home market and increasing the export of oil and its products, Pemex is spending this year alone 90,000,000 pesos for reconditioning and modernization works in the Federal District and the Poza Rica zone, Vera Cruz, it is stated by Sr. Efrain Buenrostro, Pemex general manager.

This program is the most important, in its present and future scope, and the most expensive Pemex has undertaken during the seven years it has been running the Mexican oil business. Featuring the program is the modernization and enlargement of the great refinery at Atzcapotzalco, D.F. (Mexico City suburb), established and operated, prior to expropriation, by Mexican Eagle. It includes also increased capacity for the pipeline from Poza Rica to Atzcapotzalco and various works associated with refining at Poza Rica.

This work is now making gratifying progress after having been delayed by difficulties in obtaining materials and equipment. Working area of the refinery is being expanded to 70 hectares (157.5 acres) from the 25 formerly occupied. Twenty oil conditioning towers are being installed. Concrete foundations are being placed to a depth of 18 meters each. In the construction of the reconditioned and expanded refinery, 50,000 tons of iron and steel are being used. Sixty-five percent of the material and equipment necessary for the job has been received from the U. S. and if all continues to go well with deliveries of the other 35 percent, the works will be ready for their first tests in December.

The improved Atzcapotzalco refinery will have five units, featuring towers for distillation, disintegration, and other services for the modern and efficient preparation of oil products. Crude oil delivered by the Poza Rica pipeline will be processed in first distillation, to yield kerosene, gas oil and other oil products. Surplus gases from such processing or treating will go to the hydrocarbonates plant, then to another plant where they will be mixed with gasoline of high octane, of 100, for airplanes, and of 85, 70 and 65 for land-service motors.

The Atzcapotzalco refinery will start operations with a daily production of 40,000 bbls., which will ultimately be increased to 50,000. Spheric and spheroidal tanks, some covered with floating roofs, the first of the kind to be used in Mexico.

With the reconditioning and amplification of the Poza Rica-Atzcapotzalco pipeline, it will be possible to provide with ample crude for some time to come. With three more pumping stations, the oleoduct will be able to move both oil and gas in sufficient quantities. The pipeline, which now carries 23,000 bbls. of oil daily, is to have a daily carrying capacity of 40,000 bbls.

The Atzcapotzalco refinery is also being equipped with a termoelectric plant of five units that will produce 25,000 kilowatts. The refinery's boilers will give 375,000 lbs. of steam p.h., working at high pressure.

The absorption plant, being installed at Poza Rica, is calculated to yield 75,000,000 cu. ft. of gas. The stabilization and elimination of salt from oil plant that is also being installed there, will have a daily capacity of 65,000 bbls. by filtration, clarification and purification. Large storage tanks are being placed both at Atzcapotzalco and Poza Rica. The Poza Rica absorption plant, servicing the Atzcapotzalco refinery with light products for distribution of natural gas in the Federal District, will end scarcity of that combustible in the Mexican capital.

Both jobs are being directed by Ing. Manuel Amor, director general, Ing. Jose Colomo, the coordinator general of the works, Ing. Nettell Flores, construction superintendent, and Ing. Rafael Ortiz Mena, the designer, who, with the aid of the technicians of the American purveying companies, has charge of the acquisition and placing on the various jobs of materials and equipment, and Felipe Teixidor, Pemex secretary and Sr. Buenrostro's private secretary and J. Jorge March, Pemex officials.

Winding Up War Contracts

URGED by officials of the Office of Contract Settlement, McGraw-Hill Book Company has brought out a book entitled "How to Speed up Settlement of Your Terminated War Contract". The object is to tell the average American businessman the way in which he may handle his plant operations when he receives notice of the termination of his war contracts. The author of the book is J. K. Lasser, author of the popular manual "Your Income Tax".

The book contains a complete statement of all the laws, rules regulations, forms, reports, and other government data issued to this date on the subject of termination. Much of it has been boiled down into a series of check lists that tell the large and small contractor how to proceed and how to get maximum protection in his dealings with government officials. Besides listing all the different varieties of red tape which have to be unwound Mr. Lasser supplies many hints on what contractors and subcontractors should be thinking about before and after receipt of a notice of termination, how a settlement is negotiated, how to determine what costs may be claimed, how government determinations may be appealed, and advice on numerous other points. The book is priced at $3.50.